DESIGN OF AN LMS-MEDIATED TUTORIAL TO SUPPORT DEEP AND EFFECTIVE ENGAGEMENT IN THE PROCESS OF LEARNING MATHEMATICS

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Abstract

Many institutions of Higher Learning have adopted a variety of Learning Management Systems (LMS) as platforms for e-learning implementation. However, the design and nature of LMS technologies present challenges to the design of LMS-based activities that engage students in learning to do mathematics. There are no clear guidelines or strategies for designing LMS-based activities that engage students in complex mathematical processes. Hence, using technologies in mathematics education often replicates instructivist positions and practices. Conversely, using constructivist principles, modes of mathematical engagement, and e-learning tools to mediate learning provides an integrated framework to transform the use of an LMS as a platform for e-learning implementation and promote deep engagement in mathematical learning.

The objective of this study was to explore mechanisms that could be useful for conceiving activities to support the learning of Mathematics using an LMS-mediated tutorial. The design, redesign and evaluation of the e-tutorial are reported upon. In preparation for the study, an LMS-based tutorial was designed and developed to be used as a test-bed to investigate how these e-learning tools could support learning to do mathematics. A Trigonometry module, consisting of course content in the form of resources and tasks to help the students to explore, practice and apply right triangle concepts, was used to investigate and derive design strategies. A mixed method research approach with a reflexive self-study research design was used. A group of first-year university student volunteers studying mathematics in the mechanical engineering department were used to test the tutorial. The students were asked to do a series of tasks using the e-learning environment during the Mathematics tutorial period. Data was collected using in-class observations, interviews, screen capture videos, student-written responses, and system-generated data. All students were encouraged to complete a learning journal detailing their experiences during the tutorial using an LMS-based tool. The students were given no training, but a tutor (researcher) was available to answer any questions they may have had.

Contradiction analysis was used to evaluate the data, compare purpose and practice and judge whether the activity or tool was fitted for the intended purpose. Findings were in the form of transformations of the e-tutorial system as it was developed. Among the most noteworthy contributory modifications were changing from 1) “read first, then do” to “do first, read when necessary”, 2) “work on the computer” to “work on paper then capture on the computer”, 3) “physically separated work with computer-enabled social contact”, to "individual computer work in face-to-face social settings.” 4) “single-level of resource provision” to “multi-level, demand-driven resource provision” and 5) “self-regulated” learning process regulation to “computer-assisted” learning process regulation.

The discussion of these findings indicated that to enable students’ deep and effective engagement in the process of learning fundamental trigonometry within an LMS-mediated tutorial, one needs to design the system with some activities that can create a demand for knowledge, encourage rough work and face-to-face social interaction, supported by multi-level, demand-driven resources, and computer-assisted learning-process regulation. Contributions to research by this study were in the form of 1) Design Principles for LMS-mediated tutorials, 2) Principles for an e-tutorial development methodology, and 3) The LMS-mediated tutorial system.

Keywords: Learning Management Systems (LMS), e-learning implementation, mathematics education, Constructivist principles, mixed method research, LMS-mediated tutorial

Declaration

I hereby declare that this study represents original work by the author and has not been submitted to another university. Where use has been made of the works of others, this has been duly acknowledged.

Signed by

Stephen Kigundu

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1 RESEARCH CONTEXT

1.1 Introduction

One of the profound challenges for higher education lectures in the modern world is how to harness the complex array of technology tools to provide learning environments that facilitate the learning of students with diverse backgrounds and learning preferences. Determining such an environment's features that reflect student needs requires careful deliberation and calibration. In this study, the Learning Management System (LMS) is considered one of the tools used for creating such an environment in higher education. In an LMS environment, the quality of student engagement is paramount in the design and structure of learning objects offered to students.

1.2 General Context

This study was conducted at Walter Sisulu University (WSU), which provides access to knowledge to diverse students from mainly rural, poor and disadvantaged communities (Dwayi, 2011). A situational and needs analysis conducted in 2008 at WSU identified the following as some of the challenges facing the institution:

- low throughput rates.
- a large number of first-year students lacking computer and general academic skills.
- use of traditional teaching methods (Dwayi, 2011).

Moreover, many first-year students are under-prepared for higher education; thus, innovative learning intervention strategies are needed for them to succeed (Makala, 2017).

In line with national benchmarks, e-learning was identified as an appropriate tool to support and improve the institution's quality of teaching and learning (Dwayi, 2011). There was a need to invest in Information and Communication Technologies (ICT) to enable students to learn to work with ICT in their daily activities and to provide easier access to educational materials and information to bridge the gap between secondary and tertiary education. In 2009, Blackboard LMS was adopted as a platform for e-learning and was later named WiSeUp to match the institution's image. According to Green and Gilbert (1995), such an environment would ideally support the following transitions in teaching and learning :

1. from passive reception (as in lectures) to active engagement in constructing knowledge through tools that facilitate learning.
2. from text (as in blackboard notes and printed hand-outs) to multimedia multiple representations.

3. from coverage (learning purely for examination purposes) to mastery (learning for competence in the subject).
4. from consideration of ideas and concepts in isolation to examining their meaning and applications in various contexts.

This research arose from the researcher's work at Walter Sisulu University as an e-learning specialist tasked with developing e-learning systems at the university. The researcher's role was to advise and capacitate lecturers on using technology to support teaching and ensure student participation in e-learning in line with the WSU eLearning Strategy (Dwayi, 2011). The researcher's background in mathematics education generated the initial focus to develop and research e-learning systems to support mathematics learning at the university. This project focused on the learning of mathematics for engineering.

1.3 Clarification of Terms

This study uses Several terms that sometimes mean different things in different contexts. To avoid miscommunication between the researcher and the reader of this thesis, clarifying how these terms are used in the context of this study is considered necessary at this juncture. The aim is to create clarity and eliminate misunderstanding.

1.3.1 e-Learning

There are several definitions of e-learning and several alternative terms to describe it in the literature (Brenton, 2008; Manochehr, 2006; Sangrà et al., 2012; Seok, 2008). These all refer to educational processes utilising information and communications technology (ICT) to mediate learning and teaching activities. The definition of e-learning adapted and adopted as a starting point for this study is "*e-Learning is the effective teaching and learning process delivered by combining electronic content with the tutor and student support along with community engagement"* (Kumpikaite & Duoba, 2012, p. 130).

1.3.2 Student Engagement

Kong, Wong, and Lam define student engagement as "students' psychological investment in an effort directed toward learning, understanding, or mastering the knowledge, skills, or crafts that academic work is intended to promote" (Kong et al., 2003, p. 5). Accordingly, engagement is a process in which students make multiple and varied responses, through creative and sustained reflections, to instructional cues (Schone, 2007). This engagement could be cognitive, affective or behavioural (Chapman, 2003). This study summarises the above definitions into a simple definition: *Student engagement is the student's active participation in the learning process.*

1.3.3 Learning Management System (LMS)

Learning Management Systems (LMS) form a centralised learning environment from which cognitive tools can be launched (Kigundu, 2014) and used for distributing, tracking, and managing courses (Islam & Azad, 2015). LMSs contain e-tools (for example, chat rooms, whiteboards, discussion forums, polls, quizzes, and surveys) which allow the instructors and students to share course content and communicate online synchronously and asynchronously (Naveh et al., 2010).

1.3.4 e-Tutorial

In this study, the term e-tutorial refers to an LMS-mediated tutorial that can support a reasonable engagement process in learning first-year engineering mathematics.

1.4 The Problem Statement

Mathematics is a service subject used as a tool across all the different departments of the school of engineering to solve different kinds of problems in engineering contexts. This requires students to be mathematically competent. However, entrance test results at WSU indicated that the gap between high school and university mathematics seems large, as is also the case nationally (Basitere & Ivala, 2014; Engelbrecht et al., 2005). This is especially true for trigonometry, which has been identified as one of the challenging topics for both students and teachers (Basitere & Ivala, 2014; Kamber & Takaci, 2018; Yusha'u, 2013). In the South African context, by the time students start university, many would have forgotten about basic trigonometry since are they likely to have last encountered it in high school, grade 10. There is a need for ongoing support for first-year students to bridge this gap. One possible solution is the use of e-learning support materials. However, current e-learning tutorial systems support drill and practice, factual memorisation and recall. Such environments are unsuitable for enabling the desired transition in teaching and learning identified by the university. This project involved designing an e-tutorial that can support a reasonable engagement process in learning first-year mathematics at WSU, focusing on basic trigonometry for engineering, which is needed in solving two- and three-dimensional problems encountered in civil, electrical and mechanical engineering studies.

1.5 Research Goals

Research goals are objectives to be reached through the research process (MacDonald, 2008). This study explored the process of designing an LMS-mediated tutorial guided by the research goals outlined below:

1. Understand the design process for such a tutorial system.
2. Identify conceptual models helpful for this process.
3. Derive design principles.

To achieve these goals, several subordinate goals will need to be addressed:

a) Study how the students were able to interact with the system.
b) Study the nature of students learning during the process.
c) Study the effect of the systems environment on the learning process.
d) Study the development of the system.
e) Infer design strategies to help instructional designers/lecturers develop an effective LMS-mediated mathematics tutorial.

These goals will provide insight into and answers to the following research question:
What are the design principles for a Learning Management System mediated tutorial that enables students' deep and effective engagement in learning fundamental trigonometry?

The research was organised with the help of the following sub-questions:

1. ***What is the quality of the student learning afforded by the tutorial system?***
   This question refers to the effectiveness of the e-tutorial or the extent to which objectives are achieved, particularly what students could do due to their engagement in the learning process.
2. ***How does the e-tutorial system design affect the engagement process?***
   This refers to the design of the e-tutorial, particularly how e-tutorial tools facilitate or constrain the engagement process and the role of these tools in resolving contradictions/disagreements between different goals.

3. ***How does the e-tutorial system engage students in the learning process?***
   This question refers to the students' use of the e-tutorial, particularly the success and challenges experienced during the process.

4. ***What principles about learning (learning model) may lead to an effective tutorial design for active engagement and why?***

1.6 Research Context

This study investigated how the research problem, as mentioned earlier, and objectives can be achieved through an LMS-mediated tutorial to learn foundational trigonometry. Hence, this study is positioned in the field of ICT in education or e-learning. It primarily involves using various instructional formats and methodologies in learning, supported by information and communication technologies (De Villiers, 2005) by combining electronic content with tutor and student support and community engagement (Kumpikaite & Duoba, 2012).

The rapid expansion of ICT has resulted in the availability and broader range of services for teaching and learning. This has opened up options for teachers to innovate instruction and provide new ways for students to experience learning (Rickard, 2010). As a result, many trending topics of interest and issues are under consideration in this field. Examples include; 1) the availability of informal learning opportunities in everyday life and learning (Hillen, & Landis, 2014), 2) the ease of access to multimedia content (data, voice, and video) that is accessible through portable handheld devices (such as smartphones and tablets) any time anywhere (ubiquitous) (Daughtery & Berge, 2017), 3)the use of social media platforms as performance support tools for on-demand learning, (Dzvapatsva et al., 2014) and 4) the shift in focus from educators as the owners of knowledge to the students as knowledge seekers and creators (Daughtery & Berge, 2017). This complex array of technology tools presents an enormous challenge for higher education lectures. This study addresses this challenge by exploring using an LMS as a centralised learning environment from which e-learning tools can be organised and launched (Kigundu, 2014). The researcher was interested in the issue of design for engagement and deep learning, rather than drill and practice, as well as the complexity of the design process when this orientation is taken. This study looks at how this can be achieved through an LMS-mediated tutorial that enables deep and effective engagement in the learning of foundational mathematics, in particular trigonometry. Previous studies focusing on teaching material development while adopting LMS tools to mediate students' engagement in learning are under-researched. To contribute to this gap, this study explored the principles for the design of an LMS-mediated tutorial.

1.7 Research Design

This study used a Design Research Methodology (Blessing & Chakrabarti, 2009) to merge research and practice while responding to the research objectives. In other words, the methodology above was used to understand the cyclical design process for an e-tutorial system, identify conceptual models useful for this process and infer design strategies for such an e-tutorial system.

In preparation for the study, an e-tutorial was designed and developed to be used as a testbed to investigate how these e-learning tools could support learning to do mathematics. A Trigonometry module, consisting of course content in the form of resources and tasks to help the students explore, practice and apply right triangle concepts, was used to investigate and derive design strategies for the e-tutorial.

The study followed a reflexive self-study research design and a qualitative methodology (Kigundu, 2016). This tutorial was piloted with a group of first-year university student volunteers studying mathematics in the mechanical engineering department. The students were asked to do a series of tasks using the e-learning environment during the Mathematics tutorial periods. Data was collected through questionnaires, interviews, observations, screen capture videos, and journals. The students were given no training, but the researcher acted as a tutor to respond to any challenges.

Contradiction analysis was used in data evaluation to compare purpose and practice and judge whether the activity or tool fit the intended purpose. The results of the first phase (Cycles 1 and 2) indicated several challenges encountered by the students. Design objectives were derived from these challenges to adapt and further develop design strategies for the study's second phase (Cycles 3 and 4).

1.8 Significance of the Study

Studies conducted in the field of e-learning in higher education include but are not limited to sub-fields such as distance learning, interactive learning, online learning, virtual learning, computer-based learning, digital learning, blended learning and LMS usage (Brika, Chergui, Algamdi, Musa, & Zouaghi, 2022; Sharifov & Mustafa, 2020). In the sub-field of LMS usage, the design and nature of LMS technologies present challenges to the design of LMS-based activities that engage students in learning (Hoogland & Tout, 2018). In this regard, the present study is significant because it presents guidelines and strategies for designing an LMS-mediated tutorial system to engage students in learning mathematics. Contributions from this study to research in the e-learning field are in the form of:

1) design principles for deep and effective engagement in learning basic trigonometry within an LMS-mediated tutorial system.
2) guiding principles for researchers interested in conducting design-based research on e-tutorial system development.
3) design artefacts in the form of the e-tutorial system and activities developed by the researcher.
4) areas for further and more extensive research in e-tutorial design and development approaches.

The results of this study may benefit higher education lecturers to design and structure quality student engagement in learning by using LMS mediated tutorials.

1.9 Structure of Thesis

Chapter 1: Research Context.

This chapter presents the motivation, background and statement delineating the research problem. It provides the context of the problem and identifies the purpose of the study. It overviews the methodological base and research design. It also discusses the significance of the study in its relationship to students' deep engagement supported by the LMS environment.

Chapter 2: Engagement with the Field.

This chapter presents a literature review of research synthesising the wide range of topics of importance impinging on this study. Amongst them is the research that has been undertaken on mathematical education, what it means to be competent and be able to use mathematics well and also mathematical engagement as vital to the development of mathematical knowledge and strategies and also for continued participation in the subject (Ingram, 2013). Second is the research on using ICT to support mathematical engagement, mainly using various instructional formats and technological methodologies in learning. Thirdly is the research undertaken on instructional design as a technology for developing learning experiences and environments that promote the development of specific knowledge and skills by students. Finally, the review covers research on learning approaches and principles of sound pedagogical practice.

Chapter 3: Analytical Framework.

This chapter uses a theoretical framework (Activity theory) to clarify the central concepts that informed this research. These activity theory concepts are linked to tools describing how activity theory is used as an analytical framework in this research. These concepts formed the basis for several Activity theory-based tools used to describe, analyse and evaluate student engagement. Lastly, the fundamental principles of Activity theory were applied by translating components of the activity system (Engeström, 1987) in terms of the investigated activity. The eight-step model (Mwanza, 2001, 2002) was used to model the research components.

Chapter 4: Research Methodology.

In this chapter, a design research approach that was used to explore the design of an LMS-mediated tutorial is described. The qualitative techniques and tools adopted and adapted for data collection, including the detailed procedures of how these techniques were used, are also outlined. The research process is also explained in an iterative and cyclical process of three distinct phases: the Preliminary Phase (prepare for the experiment), the Intervention Phase (test and formatively evaluate in the classroom) and the Evaluation Phase. The framework used to undertake and explicitly describe a systematic qualitative data analysis is also explained. The chapter concludes with the quality and ethical considerations taken to ensure that a study's findings can be trusted.

Chapter 5: Tutorial Design and Development.

This chapter presents qualitative and quantitative data and articulates the results from the design of the trigonometry tutorial and its development through the different research cycles. In addition, the analytical basis and development of the tutorial items and how these have been deployed are discussed. This chapter also explicates, with examples, the formulation and justification for different activities incorporated into the tutorial.

Chapter 6: Results Phase 1

This chapter presents the results from the implementation of Phase 1 (Cycles 1 and 2) in terms of in-class observations, interviews, questionnaires, screen capture videos, and system-generated data. For each modality, a brief process of data collection is described. Then a summary of the results is provided, followed by a brief discussion of factors that enabled or constrained engagement in the activities that emerged from this data modality.

Chapter 7: Results Phase 2

This chapter outlines revisions to the model implemented in Phase 1. The results from the implementation of Phase 2, generated from cycles 3 and 4, are presented for each data collection modality. A summary of the results is provided, followed by a brief discussion of factors that enabled or constrained engagement in the activities that emerged from this data modality.

Chapter 8: Findings and Discussion.

This chapter organises and presents the study's findings by identifying themes that emerged from the initial results in Chapter 6 and Chapter 7. It also provides research-based insight into the four research questions. These findings are then organised into local themes of regularly occurring insights into student engagement identified during Level-one analysis and the organisation of results.

Chapter 9: Conclusion and Recommendations

This chapter starts with a summary, and conclusions and recommendations for practice from the study are provided. In addition, some suggestions for future research studies that build on the findings from this research are also offered.

2 ENGAGEMENT WITH THE FIELD

2.1 Introduction

This literature review engages with developments in the field of ICT in education or e-learning, which relate to building a framework for the study of the design and development of an LMS-mediated tutorial, which enables students' deep and effective engagement in the learning of foundational mathematics, in particular in trigonometry. The objective is to comprehend the current state of knowledge in this field to inform this design process and understand how this research may contribute to the knowledge of the field. It will be necessary to address content, pedagogical, and technology knowledge concurrently as a framework for technology integration (Harris et al., 2009). This literature review covers developments in mathematical engagement (content knowledge), instructional/learning design (pedagogical knowledge) and e-learning (technology knowledge). Student engagement is also included because of its importance for evaluative purposes.

Institutions in South African rural areas (e.g., WSU) are flooded with first-year students characterised as under-prepared (Mbodila et al., 2016). Students generally enter higher education with gaps in the knowledge and skills required for studying, particularly in critical areas such as mathematics (Jaffer et al., 2007) and language competency (Mdepa & Tshiwula, 2012).

In mathematics, trigonometry has been identified as one of the challenging topics for both students and teachers (Kamber & Takaci, 2018; Yusha'u, 2013). For example, Blackett and Tall (1991) recognised that the definition of trigonometric functions in a right triangle is very problematic for students. There are many abstract ratios, and students are expected to manage arbitrarily rotated right triangles that even graduate students specialising in mathematical education experience difficulties when dealing with trigonometric tasks (Yiğit Koyunkaya, 2016). Under-preparedness relates to knowledge and basic skills, such as selecting the correct trigonometric ratio to use (Brijlall & Niranjan, 2015).

Since learning mathematics is a complex process, modern methods of teaching mathematics include but are not limited to problem-solving, group work, computer-assisted instruction, and interactive techniques (Nneamaka, 2013). The focus of mathematical learning has shifted from rote learning to concept learning and understanding the why behind mathematics (Ingram, 2013). This study looks at how this can be achieved through an LMS-mediated tutorial that enables deep and effective engagement in the learning of foundational mathematics, in particular in trigonometry, thus contributing to the movement from drill and practice or transmission type learning to engaged learning.

2.2 Mathematical Engagement

Mathematical engagement is vital to acquiring mathematical knowledge and strategies and for continued participation in the subject (Ingram, 2013). Mathematical engagement has commonly been used in mathematics education research to indicate that learning is taking place (Ingram et al., 2016). However, it is subject to various interpretations by researchers in different contexts. This raises several definitional, conceptual, and theoretical issues regarding the nature and role of mathematical engagement (Azevedo, 2015). Therefore, it is essential to understand what the concept of 'mathematical engagement' means and to describe the source of engagement and its measures (Sinatra et al., 2015). The following sections articulate a theoretical framework which will be used to describe and analyse mathematical engagement within the context of this study.

2.2.1 Conceptions of Mathematical Engagement

Historically, different conceptions of what mathematical engagement entails can be found in the form of theories of learning mathematics which have been proposed to guide students, teachers, and researchers in mathematics education. Discussed below are four influential models of mathematics learning which informed this study.

The first model stipulates that mathematics learning and instruction should focus on mathematical proficiency or students' mathematical knowledge and capability (Kilpatrick et al., 2001). Based on important developments identified from research in learning and instruction of mathematics, mathematical proficiency is defined in terms of five strands: 1) conceptual understanding, i.e., "comprehension of mathematical concepts, operations, and relations", 2) procedural fluency, i.e., "skill in carrying out procedures flexibly, accurately, efficiently, and appropriately", 3) strategic competence, i.e., "ability to formulate, represent, and solve mathematical problems", 4) adaptive reasoning, i.e., "capacity for logical thought, reflection, explanation, and justification" and 5) productive disposition, i.e., "habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's efficacy" (Kilpatrick et al., 2001, p. 5).

Kilpatrick et al. (2001) observed that these five strands are interwoven and interdependent. This implies that Mathematics learning should involve an integrated and balanced development of all five strands of mathematical proficiency. This study attempts to explore how in the e-tutorial design, attention can be given to developing all strands of proficiency.

The second model stipulates that the goal of mathematics learning is the acquisition of a mathematical disposition rather than a set of isolated concepts and skills (De Corte, 2004). According to De Corte (2004), the focus of mathematics learning and instruction has shifted from considering mathematics as a collection of abstract concepts and procedural skills to be mastered to viewing it as a set of "human sense-making and problem-solving activities based on mathematical modelling of reality" (De Corte, 2004, p. 280). Such a disposition requires the mastery of five categories of aptitude:1) a well-organised and flexibly accessible domain-specific knowledge base in the form of mathematics content, 2) heuristic methods which induce a systematic approach to problem-solving, 3) meta-knowledge about one's cognitive functioning and motivation that can be used to improve volitional efficiency, 4) self-regulatory skills, which embrace cognitive self-regulation and purposeful self-regulation, 5) the social context in which mathematical activities (i.e. mathematical learning and problem solving) take place.

One of the problems of mathematics learning is that students often possess specific knowledge and skills but cannot access or use them when necessary to solve a given problem. The e-tutorial should help students overcome this problem by considering mathematics appropriate to a problem, persevering in more challenging problems, taking responsibility for their learning, and developing good work habits in mathematics. This should result in the student gaining relational understanding (knowing what to do and can explain why) of the topic and not just instrumental understanding (knowing a rule or procedure and the ability to use it) (Skemp, 1976; Skemp, 2012).

The third model stipulates that to promote understanding of a given topic, a good teacher needs to look at the knowledge package (i.e., other topics related to its learning) for the topic to be taught (Ma, 1999). Ma contends that knowledge packages are important because, from this information, a cohesive and comprehensive picture of a mathematical topic can be constructed. Underdeveloped knowledge packages can present difficulties in the planning and facilitating course activities. A knowledge package includes five key components (Confer & Ramirez, 2012, p. 95): 1) conceptual knowledge, which covers the overarching ideas and facts that are foundational for the understanding of the topic; 2) skills and procedures that help in solving problems fluently and efficiently; 3) representations or models that make concepts, relationships and interdependence of the topics within a knowledge package clear; 4) strategies or approaches for accomplishing a task that helps to make sense of the mathematics; 5) mathematical language vocabulary, terminology, or phrases that are necessary for participation in discussions about the topic. These key components contain implicit sequences of student learning, through which a student learns key related pieces of content before they can grasp the entire topic at hand. The sequences are the main paths (or learning trajectories) through which students need to be engaged to develop knowledge and skills about the topic. Consequently, knowledge packages provide a basic pattern for learning and teaching mathematics.

The fourth model stipulates that learning mathematics means active involvement in an ongoing learning process (Sfard, 1998). Hence, the focus should be on activities (knowing) and not on the product (knowledge). Learning is conceived as a process of participation in shared learning activities and becoming a member of a specific community. This entails the ability to communicate in the language of this community and act according to its norms. In learning-as-participation, students contribute to the existence and functions of the community of practitioners and learning is mediated by the community. Students are newcomers, potential reformers of the practice, and teachers are the preservers of its continuity (Sfard, 1998). This approach, which characterises learning as participation in a social community of practice, seems to be in contrast to the more prominent acquisition approach in which learning is described as knowledge acquisition. However, Sfard (1998, p. 10) argues that despite this dichotomy, these approaches are not mutually exclusive categories but complementary ways of thinking about learning, illuminating different aspects of the complexity of learning. This implies that mathematics learning requires a combination of the acquisition and participation approaches to take advantage of their strengths and simultaneously reduce their shortcomings. The discussion above suggests that the design objective of the e-tutorial and mathematical engagement should be the acquisition of a mathematical disposition through:

- a balanced and integrated development of all five strands of mathematical proficiency.
- knowledge packages that provide an important pattern for teaching mathematics.
- learning that requires a combination of the acquisition and participation approaches to take advantage of their strengths and, at the same time, reduce their respective shortcomings.

2.2.2 Modes of Mathematical Engagement

Modes of mathematical engagement define what students should know and be able to do due to their engagement in mathematics learning. General ways of thinking and acting need to be identified to clarify and describe mathematical engagement. The Mathematics Learning Committee (NLC) (Kilpatrick et al., 2001), the TIMSS (Mullis et al., 2005) and PISA assessment groups (OECD, 2003) developed several conceptual frameworks aimed at clarifying and describing mathematical engagement. Different forms of engagement can be identified from these frameworks, which complement each other and constitute the complex process of doing mathematics. A synthesis of the frameworks mentioned above, combining their salient points, indicates eight complementary modes of mathematical engagement.

1) Interpretation: Make a mathematical sense of a situation by aligning it with mathematical tools and choosing the most suitable links for the task.
2) Communication using natural language: Use known, familiar language to formulate and convey reasoning and understanding.
3) Mathematical representations: Work with mathematical models (terms, symbols, pictures, and graphs) to construct and manipulate mathematics statements.
4) Procedural mathematics: Use the correct procedures, skills, and facts to solve problems accurately, flexibly, efficiently and appropriately.
5) Conceptual mathematics: Identity and accurately apply mathematical concepts to solve problem terms, principles, operations, and relations.
6) Patterns, reasons, and justifications: Use arguments (based on reasons, observations, and mathematical relations) to make sense of the situation, justify judgments and draw conclusions.
7) Evaluation and critical analysis: Identify and discuss possible weaknesses and strengths of mathematics tools when applied to a given situation.
8) Decision-making and strategic thinking: Make decisions to guide the mathematical process (work on task) and application of mathematics. Analyse the situation in order to decide what mathematical tools and processes to use.

These modes of mathematical engagement defined the scope of students' engagement in learning trigonometry during the LMS-mediated tutorial. This study thus took modes of mathematical engagement as its initial focus and explored how the LMS-mediated tutorial design can support mathematical engagement. However, this engagement can require simple, automatic functioning or complex, creative and sustained reflection or anything in between, resulting in a continuum of different levels of cognitive complexity, as discussed in the next section.

2.2.3 Levels of Mathematical Engagement (Cognitive complexity)

Cognitive complexity refers to the thinking processes required when solving a task (Stein et al., 1996). Separating the dimension of cognitive complexity from the particular mode of performance allows engagement with each mode of performance at all levels of cognitive demand (Brown, 2010). For example, initial exposure to any performance mode can occur through cognitively low-level, simple and accessible tasks. As proficiency is built, possible engagement can become more complex, allowing for higher levels of cognitive demand. This study noted that the analysis of cognitive demand for mathematical tasks is differentiated at four action levels (Stein et al., 1996).

Level 1: tasks require simple, automatic responses,

Level 2: tasks require procedures without connections to concepts,

Level 3: tasks require procedures with connections to concepts,

Level 4: tasks require complex, creative and sustained reflection (doing mathematics)

The Task Analysis Guide (Stein et al., 2000) differentiates low-level (1 and 2) and high-level (3 and 4) mathematical tasks. It provides a general list of characteristics of low-level and high-level mathematical tasks. These characteristics can be used to analyse the potential of tasks to support students' thinking and reasoning and to match tasks with their goals for student learning in order to build student capacity for mathematical thinking and reasoning.

This study explored the possibility of facilitating high-level engagement with mathematics (levels 3 and 4). At these levels, the teaching and learning of mathematics shifts the focus from students learning *about* the subject to actually *engaging* in doing it. This exposes another layer of qualities/attributes of engagement. According to Stein et al. (2000, p. 16), doing mathematics requires students to:

- focus on using procedures to develop a deeper understanding of mathematical concepts and ideas.
- investigate and grasp the nature of mathematical concepts, processes, or relationships.
- access relevant knowledge and experiences and utilise them in working through the task.
- analyse a task and actively examine task constraints that may limit possible solution strategies and solutions.
- put in significant cognitive effort in order to achieve worthwhile results.
- exercise self-monitoring or self-regulation of one's cognitive processes.

In this study, it was noted that doing mathematics can be challenging since the actions described above happen almost spontaneously, with the student using them concurrently and inter-relating them. Secondly, thinking separately about having them is useful since having these attributes can boost engagement in doing mathematics. As discussed in the next section, these attributes can be developed through what Ingram (2013) calls mathematical engagement skills.

2.2.4 Mathematical engagement skills

Mathematical engagement skills are actively fostered abilities rather than developed as a habit over time (Ingram, 2013). Ingram's analysis of students' descriptions of different pathways they usually took when attempting a mathematical task revealed individual students' mathematical engagement skills, detailed below.

- Perseverance: Continuing to do a mathematical task, despite experiencing difficulty.
- Integrity: Commitment to searching for mathematical truth and understanding – searching for more than the correct answer.
- Intimacy: engaging emotionally with mathematics.
- Independence: Solving problems autonomously.
- Concentration: Remaining focussed on mathematics and continuing engagement despite disruptions.
- Utilisation of feelings: Being negative micro-feelings and using them as a signal to persevere or change strategy.
- Cooperation: Discussing mathematics with others, solving tasks cooperatively, and asking for help as a strategy rather than as a form of disengagement or dependence on others.
- Reflection: Being self-aware. Reflecting on own and others' engagement.

In this study, mathematical engagement was evaluated according to how LMS-mediated tutorial enabled students to actively foster some or all of these mathematical engagement skills. In this way, this study tried to take the understanding of mathematical engagement a step deeper than focusing only on the level and include the quality of students' engagement in mathematics in terms of these engagement skills.

2.2.5 Indicators of mathematical engagement

The modes, attributes, and skills of mathematical engagement can be described as the dimensions of mathematical engagement, the student's specific goals for their actions can be defined as the source or object of engagement, and these goal-directed actions' descriptions can be used as mathematical, or object of engagement indicators as indicated in Table 2.1.

The indicators in Table 2.1 may be identified based on the preceding discussions of modes and attributes of mathematical engagement. This table will be used as an analytical tool for students' interaction with the LMS-mediated tutorial. For this purpose, each action is formulated as a direct verb, possibly with a modifier, to fit the source/object of the engagement idea. For example, 'think strategically' is used instead of 'strategic thinking.

Table 2.1: Indicators of mathematical engagement

Dimensions of Mathematical Engagement	Goal-Directed Actions	Description	Source
Modes	a) Communicate	Use natural language to formulate/convey reasoning/understanding.	Kilpatrick et al. (2001) OECD (2003), Mullis et al. (2005)
	b) Formulate conceptually	Identify and accurately apply mathematical concepts to decide what mathematical tools and processes to use.	
	c) Decide	Determine what mathematical tools to use.	
	d) Evaluate	Identify and discuss possible weaknesses and strengths of mathematics tools when applied to a given situation.	
	e) Interpret	Make mathematical sense of a situation.	
	f) Solve procedurally	Use appropriate procedures, skills, and facts to answer problems.	
	g) Represent	Construct and manipulate mathematics statements.	
	h) Think strategically	Decide what mathematical process to use.	
Attributes	i) Access	Access and appropriately utilise relevant knowledge and experiences in working through the task.	Stein et al. (2000, p. 16)
	j) Analyse	Analyse a task and actively examine task constraints that may limit possible solution strategies and solutions.	
	k) Focus	Pay attention to developing deeper levels of understanding.	
	l) Explore	Study and figure out the nature of mathematical concepts, processes, and relationships.	
	m) Put in effort	Put in significant cognitive effort in order to achieve worthwhile results.	
	n) Self-regulate	Exercise self-regulation of one's cognitive processes	

This study noted that only some of the actions (mentioned under modes, attributes, and skills) serve as the source or object of engagement. Others (such as persevering or maintaining concentration) are about regulating engagement, not generating engagement. Others (like developing independence and intimacy) are about longer-term disposition resulting from engagement. For example, the reason for engaging in mathematics problem solving is to find a solution, not to develop independence. But mathematics problem solving can develop independence after a while. This study explored how to develop student engagement; therefore, these were not considered useful indicators of engagement.

2.3 e-Learning Overview

This study takes a broad approach to e-learning, incorporating various forms of educational technology and online and offline learning. This approach is founded on an expansive definition of e-learning as '*learning supported by information and communication technologies* (Zhiltsov & Maev, 2020, p. 2911). This definition suggests that e-learning is not simply the possession of ICT skills but primarily involves the use of various instructional formats and technological methodologies in learning, particularly the use of software, the Internet, online learning or any other electronic or interactive media (De Villiers, 2005; Zhiltsov & Maev, 2020). This study aims to identify e-learning tools and methodologies that can be used to support mathematical engagement. As a result, this section explores how e-learning principles and models that have been successful in the past, informed by current trends, can be used to design and develop an LMS-mediated tutorial that enables students to have deep and effective engagement in learning foundation trigonometry.

2.3.1 A Brief History of e-Learning

Online learning can be traced back to the 1980s with the use of "computers to replicate autocratic teaching styles" designed for knowledge transfer (Rickard, 2010, p. 3). The major events of e-learning history have been:

- 1924, the first testing machine was invented. This device allowed students to test themselves.
- 1954, the "teaching machine" for administering programmed instruction enabled schools to manage teaching and learning.
- 1960, the first computer-based training program, known as PLATO (Programmed Logic for Automated Teaching Operations), was introduced to the world. It was initially designed for students attending the University of Illinois but ended up being used in schools throughout the area. At the same time, the Internet based on the ARPANET served as the primary precursor network for interconnecting emerging regional, academic and military networks to make the World Wide Web (Rao, 2016).
- By the mid-1990s, higher education institutions explored e-learning to leverage information technology as an opportunity to extend course access to more students, improve the quality of learning, and reduce the cost of education (Twigg, 1994), innovate instruction and present new ways for students to experience learning (Rickard, 2010, p. 3). By the mid-2000s, e-learning had become an integral part of mainstream education, and training environments with a promise of more substantial learning outcomes than traditional classroom environments, and that blended learning environments offered even more significant advantages (Rickard, 2010).

E-learning unites two main areas of education; learning and technology (Aparicio et al., 2016). However, research on e-learning use in higher education institutions in sub-Saharan Africa has focused on LMS uptake and not on how to promote students' engagement in the learning process. For example, in Mozambique, Unwin et al. (2010) investigated myths and realities of LMS use; in Uganda, Mayoka and Kyeyune (2012) examined e-learning Information Systems failures and adoption problems in Ugandan universities; in Sudan, Elmahadi and Osman (2013) investigated the use of Moodle Learning Management System by Sudanese students, particularly forum and wiki collaborative tools and in Nigeria Nicholas-Omoregbe et al., (2017) focused on factors that could influence LMS adoption in higher education.

While e-learning uptake is on the rise, critics question the successes of e-learning which seem to remain within the traditional educational paradigm of knowledge transfer. For example, Weigel (Weigel, 2002), based on the work of Marton and Saljo (1976), argues that the true measure of course effectiveness is related more to whether it promotes deep learning or surface learning (see section 2.5.4). Marton and Saljo distinguished deep learning, the critical analysis of new ideas and linking them to already known concepts and principles, from surface learning, the unchallenged acceptance of information and memorisation of facts (Marton & Saljo, 1976). Most often, e-learning is criticised for the surface learning that students experience, the lack of social presence of professors, and the sense of isolation that students report (Ulmer et al., 2007; Zhang & Walls, 2009). This study tried to address this issue by designing an LMS-mediated tutorial that enables students' deep and effective engagement in learning.

2.3.2 Principles for e-Learning Implementation

Nichols (2003) observed that there existed a large number of published articles on the implementation of e-learning by institutions. However, most of the literature on e-learning at that time was practice-based and primarily descriptive in character, composed of narratives of what people have done. With few literature sources specifically concerned with e-learning theory, there is no theory for e-learning, and few theorists can be readily identified as authoritative. Rüth and Kaspar (2017) argue that this is due to the heterogeneous nature of e-learning, where it is difficult to compare different approaches characterised by unique combinations of situational factors. Comprehensive theories of e-learning that allow deductive reasoning and hence a more top-down strategy are missing so far (Rüth & Kaspar, 2017). To address this issue, Nichols (2003) collated a set of aggregated findings by researchers in e-learning, suggesting that they may serve as fundamental principles for e-learning implementation.

Firstly, e-learning should be taken as a tool that can be applied within varying education models and educational philosophies. It tends to be utilised in two fundamental ways, the presentation of content and the facilitation of learning processes. Secondly, the overall aim of education does not change when e-learning is applied. Hence the choice of e-learning tools should reflect rather than determine the pedagogy of a course. Thirdly, e-learning advances primarily through the successful implementation of pedagogical innovation. This innovation should consider how students can engage with the learning opportunities provided to them to create effective e-learning practices.

While these principles provide a good foundation for e-learning implementation, it is argued in this study presents that more details are needed to cover the process of designing e-learning environments (e.g., LMS-mediated tutorial) that can support a good engagement process in learning. This study explores the possibility of other principles that can be applied to guide the design of an LMS-mediated tutorial that enables students' deep and effective engagement in learning.

2.3.3 e-Learning Environments

e-Learning environments provide interactivity that engages students in the active acquisition and application of knowledge, principles and values and provides feedback that allows understanding to grow and evolve (Chickering & Ehrmann, 1996). They can also provide students with dynamic, interactive, nonlinear access to a wide range of information represented as text, graphics, animation, audio, and video, as well as to self-directed learning in online communication as hypertext, e-mail and forums (Kramarski & Gutman, 2006). The interaction can be with content, other students or an instructor within a space wherein the student acts.

Constructivism, with its focus on learning (not instruction), requires that rather than designing instructional sequences, the emphasis should be on the design of a learning environment which supports active learning (Lefoe, 1988). Jonassen (1999) describes four essential components of a constructivist learning environment (CLE); 1) the problem, question or project (the focus of the environment), 2) related cases (representing a set of related experiences), 3) information resources (providing information to help students comprehend and solve the problem), and 4) cognitive tools (helping to represent, organise, automate or supplant thinking skills).

The problem (question or project) provides the focus of the environment and constitutes a learning goal. The principle driving the learning process of the activities of the CLE can be tasks or questions that promote higher-order thinking (e.g., discussions, open questions, constructions or open-ended questions). In this study, the design of the questions may include a problem setting related to the application of mathematics in engineering contexts to make it interesting, relevant and authentic. E-tools can provide the problem and the problem manipulation space.

Related Cases support learning by scaffolding student memory and providing different perspectives, themes, and interpretations (Jonassen & Rohrer-Murphy, 1999). Constructivist teaching provides scaffolding through guided instruction and support using interventions such as modelling, coaching, and educational media in the form of worked examples and process worksheets.

Information Resources provide just-in-time information to help students comprehend and solve the problem. Information resources can be links to freely accessible online materials such as notes, videos, exercises, and tests. Electronic information resources have many functions and benefits (e.g., fast access to a broader range of current, up-to-date information, which can be of immense use to students (Gakibayo & Okello-Obura, 2013).

Cognitive Tools are generalisable tools that can facilitate cognitive processing.

These are sometimes referred to as learning tools (or learning objects) that have been adapted or developed to support learning (Pratiwi & Suprapto, 2021). Cognitive tools are knowledge-construction tools that extend the mind by helping to represent, organise, automate or supplement thinking skills. There are six major types of cognitive tools with different functions (Jonassen & Rohrer-Murphy, 1999).

1. *Task Representation Tools help students visualise and construct (in more than one way) mental models about the knowledge domain*. These tools assist students in perceiving the task in the same way the teacher does (Smeets & Solé, 2008). They also allow students to develop their conceptual understanding of how problems relate to domain knowledge. Examples include graphic organisers and concept maps.
2. *Knowledge Modelling Tools help the students to make their understanding of* the problem explicit. Knowledge modelling represents knowledge structures or domains by linking concepts, procedures, and principles to describe the phenomena at hand (Paquette et al., 2006). This includes "methods and techniques for knowledge acquisition, modelling, presentation, and use. Examples include grouping, labelling, matching, ranking, and sequencing.
3. *Performance Support Tools* share the cognitive loads to perform routine tasks, such as calculation and memorisation (Jonassen & Rohrer-Murphy, 1999) by providing access to specific information needed to complete a task and hence reduce the need for much prior training in order to accomplish the task

(Rosenberg, 2013). In other words, the purpose of performance support tools is to provide "just-in-time" instruction that informs and guides people through a task (Turnbow & Roth, 2019). Examples of e-learning include an online calculator, online help, a notepad, a glossary, a system map, checklists, flowcharts, and frequently asked questions and forms (Kigundu, 2016).

4. *Information Gathering* Tools help students to focus on problem-solving and not be distracted by searching for information. Examples include search engines on the WWW. Due to the large amount of data posted on the web, the web has become a prime source of information for various tasks (Alhenshiri et al., 2012).
5. *Conversation and Collaborative Tools* support social negotiation and interaction as part of the learning process. These tools help students to work with others to solve problems and to form a mutually promotive community, sharing knowledge and supporting each other. Examples include email, discussion forums, and Web 2.0 tools (McDonald & Reushle, 2001).
6. *Elaboration tools* give access to reviews and additional exercises and practices related to the content of the task (Clarebout & Elen, 2006).

In recent developments, LMSs form a centralised learning environment from which cognitive tools can be launched (Kigundu, 2014) and used for distributing, tracking, and managing courses (Islam & Azad, 2015). LMSs contain e-tools, such as discussion forums, polls, chat rooms, whiteboards, quizzes and surveys, which allow synchronous or asynchronous course content sharing and communication among students and instructors (Naveh et al., 2010). In this study, these built-in features of the LMS that support student learning are defined as *endogenous tools* in order to differentiate them from *exogenous tools*, which are any other learning tools used by students outside of the LMS.

Institutions tend to use LMSs to enhance the quality of face-to-face delivery by enabling students to independently access course content (Lee & Hsiao, 2014). Other institutions use LMSs to offer blended distance delivery across various geographical boundaries (Andersson & Grönlund, 2009; Islam & Azad, 2015). Different institutions use LMSs to offer blended distance delivery across various geographical boundaries (Andersson & Grönlund, 2009; Islam & Azad, 2015). This suggests a wide range of LMSs used to support learning. However, the use of an LMS-mediated tutorial to support students' deep and effective engagement in learning is under-researched or has not been documented. This is a gap in the literature here that this study attempts to address.

2.3.4 e-Learning More Recent Trends: 2010 onwards

Hillen and Landis (2014) point to several emerging trends in e-learning, such as the globalisation of distance education, the availability of informal learning opportunities, the ubiquity of cyberspace connections around the world and the presence of technology in daily life and learning. In this study, three observations have been made about the effect of these e-learning trends on engagement in learning.

First of all, it is noted that current innovations in e-learning are mainly technology-driven, hence the use of the term *educational technology*. Still, in some cases, it seems to present specific pedagogical values. For example, mobile learning technology offers content (data, voice, and video) that are accessible through portable handheld devices (such as smartphones and tablets) anytime, anywhere (ubiquitous) (Daughtery & Berge, 2017). It also facilitates dynamic knowledge (the sort of knowledge that is naturally and spontaneously invoked in authentic interactions in the real world), which requires individual meaning-making based on multiple sources of information (Caine & Caine, 1997). A systematic review of mobile learning functions by Bano et al. revealed three overarching emerging pedagogical frameworks: collaboration, inquiry-based learning, and realistic learning (Bano et al., 2018). Mobile learning is also characterised by authenticity and personalisation (Brown & Mbati, 2015). These pedagogies are also reflected in the use of social media platforms as performance support tools for on-demand learning, for example, YouTube videos (Dzvapatsva et al., 2014).

The second observation, based on an analysis of the evolution of e-learning and new trends (Bezovski & Poorani, 2016), is emerging personalised learning where content is no longer pushed at students. Instead, e-learning puts the students in control, allowing them to pull information as needed, creating their learning path. Students are also offered choices about how they prefer to learn and can choose mediums that suit their learning style and pace. This shifts focus from educators as the owners of knowledge to the students as knowledge seekers and creators (Daughtery & Berge, 2017). Accordingly, accessibility remains one of the fundamental attributes of online resources (Naidoo & Govender, 2014).

The third observation is the ICT usage of technology to augment traditional practice (Bray & Tangney, 2017). Examples include: 1) using ICT to change attitude, improve performance, develop conceptual understanding, and acquire skills, 2) giving students new ways to visualise concepts and approach problems dynamically; authentic contexts and realistic data used without becoming overbearingly complex, 3) supporting collaborative, problem-solving and inquiry-based approaches and using e-books (Ingram, 2013; Naseri et al., 2016) and using digital libraries and tools to save students and teachers time, while not adding complications to their already busy lives and heavy workload (Calhoun, 2014; Recker et al., 2004).

Even though many of the models mentioned above and theories have existed for a long time, institutions still need to work on integrating them into their e-learning programs. The challenge (explored in this study) lies in how to replicate easy, flexible access and a large variety of cloud-based resources (Cook, 2014; Cook & Ellaway, 2015) in an LMS environment for students to engage in the learning experience.

2.3.5 Issues relevant to this study

Recent trends, as indicated in the current literature (discussed above), raise several problems and issues in the field where the findings of this study will provide some input. In particular, the following issues were found to be relevant to the design of an LMS-mediated tutorial; 1) resource provision, 2) content design and presentation, 3) learning process regulation, and 4) LMS tools use.

1) Resource provision

Reading is critical for gaining understanding within any discipline (Sharma et al., 2019) and is an essential avenue for effective learning (Palani, 2012). However, research has identified several cases where students fail to do the required reading. These include, among others, struggling to comprehend given texts (Bean, 1996; Ryan, 2006), not having sufficient time (Barnett, 1998), confusion amongst students about what academics want them to do (Maher & Mitchell, 2010) or low confidence in the ability to complete the reading task (Tuckman, 1991). Therefore, there is a need to motivate students to read. Researchers propose several techniques to encourage students to read within learning environments, for example, through reframing the task as a challenge (Alter et al., 2010; Woods, 2003), making the challenge doable (Gee, 2005) or enabling flexible access and review of content consistent with prior knowledge (Kigundu, 2016). This study aims to add to this list by exploring how to enhance access and review content in an LMS-mediated tutorial environment.

2) Content design and presentation

As a follow-up to resource provision, designing and presenting content in the resources can be challenging. As discussed above, current trends suggest that content design and presentation should enable open access, demand-driven and purposeful media use (Herrington et al., 2001). Content should not be pushed at students; instead, the students must be able to pull information as needed. Practitioners in e-learning have some suggestions for how this can be achieved. For example, 1) segmenting; where the content is chunked into small segments and includes built-in questions, reviews, and summaries for each segment (Elissavet & Economides, 2003), 2) navigation; make the resources accessible and meaningful by providing clickable buttons to go to the next segment (Mayer & Pilegard, 2014), 3) support; incorporate help strategies, such as on-demand hints (Inventado, et al., 2018). This study explored how achieving these objectives can be possible within an LMS-mediated tutorial.

3) Learning process regulation

The shift in focus from educators as the owners of knowledge to the students as knowledge seekers and creators (Daughtery & Berge, 2017) is one of the challenges in e-learning implementation, as students need assistance to work within their "zone of proximal development" (Vygotsky, 1978). This requires learning process regulation, where learning takes the form of small segments of activities that include built-in questions and resources (Elissavet & Economides, 2003). This can be achieved through the current conditional-release tools available in many LMSs (Fisher et al., 2014). The conditional release can be taken as course content availability control based on specific student behaviour, activities, or achievements (Gardner et al., 2011). It can be action-based, achievement-based, or teacher-controlled.

Well-designed conditional release activities can help the learning process regulation, course progression, flexible course content delivery, and scaffolding facilitation efforts to support students. This is particularly true for linear progression courses. In these courses, conditional release enables the teacher to require an acceptable level of mastery before moving to the following content. The conditional release provides an interim failure and learning opportunity, allowing the student to review resources and try again (Rogers, 2002).

One primary use of conditional release is to provide a means of managing flexibility in learning, where students can bypass the material they have already mastered while forcing them to slow down and achieve an acceptable level of success for other content (Smith, 2008). Flexibility can include variations in what, when, where, and how of content delivery and addressing differences in student approaches to learning. In spite of this, Abell (2006) contends that conditional-release tools are less complex and less individualised than the tutoring systems (Abell, 2006).

The challenges (explored in this study) lie in how conditional release tools offered by LMSs can provide means to guide students through course content comparable to intelligent tutors/agents or adaptive learning environments. For example, can the system provide a "just-in-time help window" that can be set up for conditional release based on the student's progress and answers to evaluation/assessment questions or that can be triggered manually by the instructor, or be set up to trigger/become available after a predefined time activity structure?

What minimal passing grade is an appropriate threshold for conditional release (Fisher et al., 2014)?

4) LMS tools use

The basic tools of an LMS include, among others, 1) Computer-mediated communications (CMC). This includes e-mail and bulletin board facilities or real-time messages between online users; 2) Content management (i.e., dissemination of learning materials). Provision of online documents required by students such as lecture slides, module outlines, case studies, and assessment materials; 3) Computer-assisted assessment (CAA) such as multiple-choice questions, multiple answers, true/false, matching, ordering, fill-in-the-blank, fill-in multiple blanks and short answer/essay; 4) Course management facilities to control access and submission of work by students (Greasley et al., 2004).

However, LMSs are created to be appropriated (Ebbert, 2017), to enable users to invent new uses for the LMS in different ways according to their situational factors. Ebbert (2017) defined appropriation as the way in which technologies are adopted, adapted and incorporated into working practice in a way that is creative or unusual (Ebbert, 2017). For example, Byrd found online quizzes to be an effective method for engaging students to read the assigned material but not effective in assessing knowledge of posted material if given as a post-test (Byrd, 2012). In the context of LMS usage, the challenge (explored in this study) lies in how to use LMS tools to combine the provided functionalities to create structure and learning objects, such as course, modules, tutorials or activities (Hoogland & Tout, 2018). LMS functions (e.g., automated assessment) can provide space for graceful failure through immediate feedback and resources to make recovery easier (Fisher et al., 2014; Gardner al., 2011).

2.4 Instructional Design

The successful implementation of e-learning requires instructional design, the strategic planning of instruction (course) (Morrison & Ross, 2007). This study explored how instructional design principles and models that have been successful in the past, informed by current trends, can be used to design and develop an LMS-mediated tutorial that enables students’ deep and effective engagement in learning foundation trigonometry.

2.4.1 Definition of Instructional Design

Smith and Ragan (2005) contend that Instructional design is a field or set of theories for developing learning experiences and environments for promoting the students' acquisition of specific knowledge and skills. It is “ a systematic and reflective process of translating principles of learning and instruction into plans for instructional materials, activities, information resources and evaluation" (Smith & Ragan, 2005, p. 4). It is also a practice of creating instructional experiences which make the acquisition of knowledge and skill more efficient, effective, and engaging" (Merrill et al., 1996). It is also a process by which learning products and experiences are designed, developed, and delivered (Gustafson & Branch, 2002). These learning products include (but are not limited to) online courses, instructional manuals, video tutorials, simulations, etc. (Johnson, 2021; Shrock, 1995).

2.4.2 A Brief History of Instructional design

This study was interested in instructional design principles that can be useful in successfully implementing e-learning (Ramazanoğlu, 2017). This section aims to study how these instructional design principles were developed and influenced by the lessons learned from the history of instructional design. Ramazanoğlu (2017) suggests that instructional design can be traced to Skinner (1954), who introduced the idea of programmed instruction. Skinner suggested that instructional materials should include small steps, frequent questions, immediate feedback and allow self-pacing.

In 1956, Benjamin Bloom developed the "Taxonomy of Educational Objectives", identifying principal learning domains. However, the core of instructional design practices today comes from Robert Gagné's (1985) research called "The Conditions of Learning and Theory of Instruction". In this research, Gagné defined three domains of knowledge (i.e., cognitive, affective, and psychomotor), resulting in five learning outcomes (i.e., verbal information, intellectual skills, cognitive strategy, attitude, and motor skills). Gagné argued that these outcomes are achievable through nine events of instruction (i.e., gain attention, objectives presentation, prior learnings, content presentation, learning guidance provision, performance simulation, performance assessment, performance feedback, retention enhancement and transfer) (Kang, 2004).

The influence of constructivist theory within the field of instructional design became more active in the 1990s. The objective of the Constructivists was to make learning "authentic" by producing real-world learning experiences that allow the student to form and construct their knowledge. Constructivists claim that emphasising "authentic" learning tasks and considering constructivist principles can enhance instructional design practice (Reiser, 2001).

The use of technology became more influential within the field of instructional design in the 2000s. Initially, online learning was delivered via Learning Management Systems (LMS), allowing a single, one-stop shop to manage, deliver, and track online learning courses and assessments. However, the accessibility of rich instructional media, including video and simulations, became possible as internet bandwidth improved (Kang, 2004; Reiser, 2001).

The key results of developments in instructional design are principles that may serve as fundamental guidelines for an LMS-mediated tutorial design.

2.4.3 Design of Instruction

A successful design of instruction should be based on education theory, research into learning, and practical experience (Dick & Carey, 1996). Buscombe (2013) contends that applying Gagne's nine-step model, gives lesson plans structure and a holistic view of the instruction (Buscombe, 2013). In addition, this study explores how Gagné's nine-step model can provide strategies that can be used to design an LMS-mediated tutorial. The tutorial is one of the three most common computer-assisted instruction types (Gagné et al., 1981; Kausar et al., 2008), the others being drill and practice and simulations. It is the preferred mode of instruction since it is more comprehensive and can stand alone.

2.4.3.1 Gagne's model of instructional design

A typical procedure for tutorial programs involves the following actions: present information, ask questions, judge responses, and provide feedback (Gagné et al., 1981). This procedure is founded on the nine events of instruction (Gagné et al., 1981; Gagné et al., 1992). Gagne's instructional design model replicates what happens to adults' minds when exposed to different stimuli and focuses on the learning outcomes and how to arrange specific instructional events to achieve those outcomes. The nine events of instruction can be used to develop engaging e-learning experiences that offer online learners the opportunity to engage in every step of the instructional process (Pappas, 2015). The following list presents each of the nine events and examples of how e-learning tools can be used to support them.

1) Gain attention: this focuses the students' interest so that they become involved in the learning process. In e-learning, exciting devices such as videos, animation, audio, and graphics can produce attention-grabbing effects (Arshavskiy, 2016).

2) Inform students of objectives: this allows the learners to organise their thoughts on what they will learn and perform. e-Learning enables the presentation of objectives in a variety of formats, including but not limited to module pages, lecture slides, and the syllabus, as well as in instructions for activities, projects, papers, and so on (CITT, 2018)

3) Stimulate recall of prior learning: this allows the learners to retrieve previous knowledge and skills and to build on previous knowledge or skills. In e-learning, short, online assessments can test learners' existing knowledge and serve as modules to review information (Arshavskiy, 2016).

4) Present the content: this event is where the new content is presented to the learner; sequence and chunk the information to avoid cognitive overload. For this step, e-learning can be used to create goal-centred content (Pappas, 2015) and to blend the information with relief elements like images, audio or even video to provide and retain interest and aid in information recall (Arshavskiy, 2016). Content can be posted via an LMS to allow students to access the materials outside of course meeting times (CITT, 2018).

5) Provide "learning guidance": this event means showing what appropriate actions constitute correct performance or examples. For this step, e-learning tools can enable the incorporation of help strategies, such as on-demand hints, which lead to better learning outcomes (Aleven et al., 2006), or providing worked examples (e.g., in mathematics) (Martin, 2015).

6) Stimulate performance (practice): in this event, the learner is required to practice the new skill or behaviour. Eliciting performance allows learners to confirm their correct understanding, and repetition increases the likelihood of retention. In e-learning, practice is provided through interactive activities such as quizzes or online discussions (Martin, 2015).

7) Provide feedback: in this event, the learner gets feedback. This needs to be specific, individual and immediate to provide guidance and answer any questions. In e-learning, e-learning tools have built-in features to provide feedback for interactive practice activities such as quizzes (Arshavskiy, 2016; Martin, 2015).

8) Assess performance: Evaluate the learners to determine if the students can demonstrate what they have learned without receiving additional coaching or hints. For this step, the submission of papers, tests, assignments, and portfolios (the primary methods used for student assessment) can be made electronically (Picciano, 2017), for example, using LMSs (Kigundu, 2014). The e-learning tool can also enable the use of mid-point assessments, incorporating interactive quizzes that require responses to queries before moving on and facilitating inter-student collaboration through group activities/projects (Arshavskiy, 2016).

9) Enhance retention and transfer: Inform the learners about similar problem situations and provide additional practice. Repeating learned concepts effectively enhances knowledge retention, although often disliked by students. Additionally, transferring knowledge and skills to new problems and situations can also improve retention. In e-learning, providing opportunities for discussion in small groups or using a discussion board can also enhance retention (CITT, 2018).

Applying Gagne's nine-step model provides a micro-design of strategies for creating lesson plans and procedures to carry out those plans (Richey, 2000). However, its highly structured nature is problematic and, therefore, less adaptable during implementation (Cunningham, 1996). On the other hand, Merrill's First Principles of Instruction can provide a macro-design or the overall direction on the design of instruction and implementation of these strategies.

2.4.3.2 Merrill's First Principles of Instruction

Merrill's First Principles of Instruction proposes foundational principles of instruction that, when used, are proposed to increase student learning. These are five principles of learning, namely: 1) Task-centred principle, 2) Activation principle, 3) Demonstration principle, 4) Application principle, and 5) Integration principle (Merrill, 2007; Merrill, 2010). These principles suggest the task as the central learning tool within which instruction can take place, guided by four principles to promote instruction and learning in the following manner.

1) Task-Centred principle – Students learn more when the instruction is centred on relevant real-world tasks or problems, including tasks or problems that progress from simple to complex. The introduction of the task can be used to gain students' attention and inform students of the objectives.

2) Activation principle – Students learn more when directed to recall prior knowledge, to identify a structure for organising that knowledge or are given a system for organising new knowledge. This principle can be used to stimulate the recall of prior learning, which may include a foundational learning experience for subsequent learning.

3) Demonstration principle – Students learn more when new knowledge is demonstrated through real-world tasks or problems, demonstrating both informational and skill-based knowledge. The demonstration principle can be used to present new content.

4) Application principle– Students learn more when they receive feedback and appropriate guidance when applying knowledge to real-world problems. This principle can be used to allow students to practice what they are learning and the teacher to guide and give feedback.

5) Integration principle – Students learn more when encouraged to integrate their new knowledge into their life through reflection, discussion, debate, and presentation of new knowledge. This principle suggests other forms of activities that can be used to enhance knowledge retention, transfer and assessment.

It is observed from above that Merrill summarised Gagne's nine steps into four principles. Merrills principles and Gagne's nine steps suggest starting a lesson by warming up the students using their previous knowledge and experiences with clear learning objectives. In this study, asking is taken to be a more engaging start than stating objectives since it motivates, enhances critical appraisal, literature review and encourages ongoing learning (Woods, 2003). Asking can be used as a developmental diagnostic tool (Simkins & Allen, 2000) and helps in priming the brain for what is coming (Hall, 2017). Through pre-testing, asking may be a very effective means of communicating course expectations to students (Beckman, 2008). However, the question must feel challenging but doable, and feedback informs what progress is being made (Gee, 2005)

2.4.3.3 Task-centred Cycle of Instruction

Merrill's First Principles of Instruction suggests a design framework which can be used as the guiding criteria for the effective design of instruction. A schematic overview of this design framework is provided in Figure 2.1.

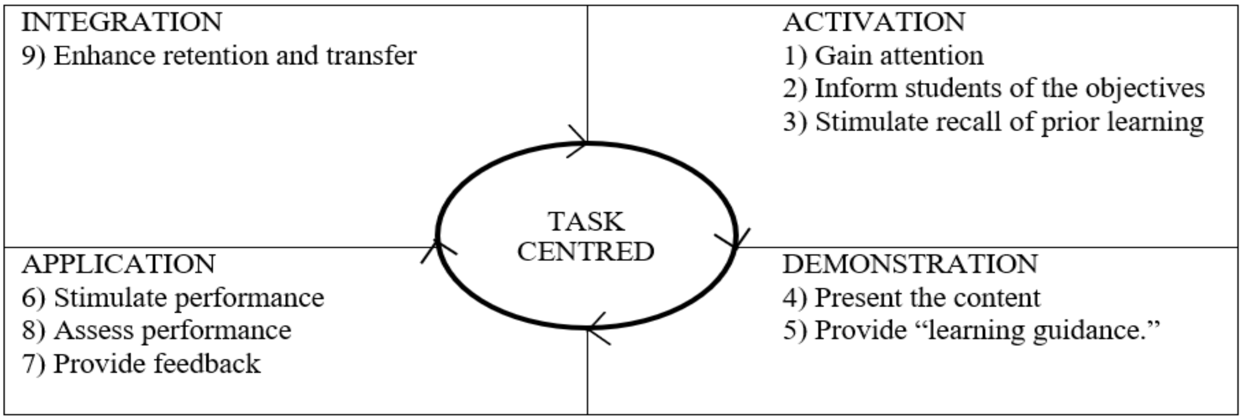


Figure 2.1: Task-centred Cycle of Instruction

(based on Merrill's First Principles (Merrill, 2007; Merrill, 2010) and Gagné's nine events of instruction (Gagné et al., 1981; Gagné et al., 1992)**)**

Figure 2.1 demonstrates that instruction can follow a task-centred instruction cycle, beginning with activation and continuing through to integration (Gardner, 2011). Gagné's nine events of instruction can be taken as instructional actions for each principle. Gardner (2011), after summarising the results from several studies using Merrill's First Principles, contends that there is some evidence that these principles increase learning and student satisfaction. However, there is a need to find ways to motivate students by promoting learning (Merrill, 2010). For example, by activating the principle of challenge-driven Instructional Design (Swan, 2008) aimed at creating an environment in which students are able to assess and develop their agency.

2.4.3.4 Swan's principle of Challenge-driven Instructional Design

Swan (2008) asserts that "crafting a *meaningful challenge* within a *self-consistent* setting that provides the *means* and the *embedded helps* to support agents' exercise of judgment and action provides an environment in which learners can test and expand their agency" (Swan, 2008, p. 200). The purpose of *embedded help*, otherwise known as *performance support tools,* is to provide "just-in-time" instruction that informs and guides students through a task (Turnbow & Roth, 2019). This warrant further exploration of how these principles operate in an e-learning setting such as an LMS-mediated tutorial environment.

2.4.4 More Recent Development: 2010 onwards

While based on theories of behaviourism, which dominated the 1950s and 1960's, modern instructional design is more contextual, fluid, and student experience-driven. Some current instructional design trends are influenced by technological advances in social media, cloud-based services, and big data (Hart, 2018).

Similar to current e-learning developments, current innovations in instructional design are also technology-driven but, in some cases, seem to present certain pedagogical values. For example, the amount of information each student needs to process has grown exponentially over the last several decades. New approaches to instructional design are in demand to turn simple cramming into applicable information processing. This is the foundation of online learning. As a result, individualisation is on the rise, where each student can get a personal approach to learning (Vaughan, 2015). Artificial intelligence can help work out individual programs for each student based on their interest and previous achievements. Unfortunately, designing such programs may take too much time (Hart, 2018).

Practically, some degree of individualisation can easily be implemented through "pull content" resources such as on-demand video libraries, nano or bite-size learning, social learning, and visual learning (e.g., infographics) (Andriotis, 2016; Hart, 2018; Vaughan, 2015). However, the availability of content resources does not create a demand for knowledge. There is a need to find ways to motivate students by promoting learning (Merrill, 2010). The focus should not be solely on learning outcomes but also on the student's overall experience that enables the student to achieve the desired learning outcome in a human-centred and goal-oriented way (Andriotis, 2016; Hart, 2018).

2.4.5 Implications for this Study

While Merrill's principles might apply universally to all instructional situations, the challenge lies in identifying the specific methods by which each principle can be implemented in each situation for high-quality instruction (Reigeluth, 2012). This study explores how Merrill's first principles can be used as the guiding criteria for designing the LMS-mediated tutorial by providing more precision with Gagne's events as the instructional actions for each principle. As this study focused on exploration instead of intervention, the specific steps used could not be applied rigidly. Instead, the steps were carefully explored to see how they could be adapted to the LMS environment.

2.4.6 Task

The concept of a mathematical task can frame the investigation of mathematical engagement. A task is a piece of work to be done (a job to do) (Oxford Advanced Learners Dictionary). So, a mathematical task is a piece of mathematical work that needs to be done, a mathematical problem to be solved. The primary goal for engaging in the task is to complete it (to finish the job) and generate the mathematical problem's solution. While a mathematical task is an activity which is intended to focus students' attention on a particular mathematical idea (Stein et al., 1996) and is an underlying goal which is important for the teacher (and for the learning) (Kilpatrick et al., 2001), it is not the key focus for the student doing the task. In other words, students' mathematical engagement is generated by the problem to be solved and not the possible learning.

Anthony and Walshaw (2007) argue that whilst the research provides evidence that tasks can justifiably vary in purpose or format, tasks should all share some commonality. They should be challenging for the student and leave something of mathematical value to the student. Tasks are central to students' learning, shaping their learning opportunities and their view of the subject matter (Kilpatrick et al., 2001). However, not all tasks offer students the same levels and opportunities for thinking. The level and kind of thinking students engage in determines what they will learn (Hiebert et al., 1997). Therefore, if students are to develop the capacity to think, reason, and problem solve, then they need to engage with high-level, cognitively complex tasks. The challenge (explored in this study) lies in how this can be achieved by an LMS-mediated tutorial through sequences of microtasks (Watson & De Geest, 2012) based on the theoretical framework discussed in section 2.4.3.

Activate

Figure 2.1 suggests that the activation principle can be used to gain students' attention, inform them of objectives and stimulate their recall of prior learning. For this step, the challenge explored in this study lies in how e-learning can be used to activate relevant cognitive structures. For example, 1) by directing students to recall, describe or demonstrate relevant prior knowledge or experience through well-designed self-assessment exercises (Georgouli et al., 2008) and 2) through intrinsic feedback to help students as they do the exercises. Moreover, reading content should be critical for understanding (Sharma et al., 2019) and is an important avenue for effective learning (Palani, 2012). This suggests that students require encouragement to spend time on content engagement which enhances critical appraisal and literature review and encourages ongoing learning (Woods, 2003). This study explores how to improve content engagement, in an LMS-mediated tutorial, without using the typical way to motivate students by stating the aims and objectives (Gagné et al., 1992). Human motivation lies in experiencing challenging but doable tasks and gaining continual feedback that lets them know what progress they are making (Gee, 2005).

Demonstration

Figure 2.1 suggests that the demonstration principle can be used to present the content or provide learning guidance. Demonstrations, as ways of providing examples of the content being taught, are fundamental for effective and engaging instruction (Merrill, 2017). The demonstration is presented to the student sequenced and chunked to avoid cognitive overload. For this step, the challenge of this study lies in how e-learning can be used to create goal-centred content (Pappas, 2015) and to blend the information with relief elements like images, audio or even video to provide and retain interest, and to aid in information recall (Arshavskiy, 2016). While content can be posted via an LMS to allow students to access the materials outside of course meeting times (CITT, 2018), using internet resources may be restricted to seeking help for solving problems (Shepherd & Van De Sande, 2014).

Application

Figure 2.1 suggests that the application principle can be used to stimulate and assess performance as students practice what they are learning and for the teacher to guide and give feedback. Stimulating performance allows students to confirm their correct understanding, and repetition increases the likelihood of retention. At the same time, the system or instructor can provide learning guidance by showing the appropriate actions that constitute correct performance or examples.

Here, the challenge in this study lies in how e-learning tools can enable the incorporation of help strategies, such as on-demand hints, which lead to better learning outcomes (Inventado et al., 2018) or providing worked examples (Martin, 2015). In e-learning, practice can be provided through interactive activities such as quizzes or online discussions (Martin, 2015), where the student is required to apply knowledge through using the new skill or behaviour, and the system or instructor can provide feedback using e-learning tools built-in features (Arshavskiy, 2016; Martin, 2015). However, the feedback needs to be specific and immediate, providing guidance and answering any questions at an individual level (Serral et al., 2016). Otherwise, these e-learning initiatives will be unsuccessful.

Integration

Figure 2.1 suggests that the integration principle can be used to enhance retention and knowledge transfer. Performance assessment is used to evaluate whether students can demonstrate what they have learned without additional coaching or hints. The challenge in this study lies in how integration can be done electronically (Picciano, 2017), for example, using the LMS (Kigundu, 2014). This study explored how e-tools can enable mid-point assessments, incorporating interactive quizzes that require responses to queries before moving on and facilitating inter-student collaboration through discussions (Arshavskiy, 2016). The assessment also provides for the repetition of learned concepts and is an effective means of enhancing retention, although often disliked by students. However, repetition does not increase transfer because students learn that specific pattern, not similar patterns to which transfer may be possible. The near transfer of knowledge and skills to new, but partly similar, problems and situations is possible through interactive activities such as quizzes (Martin, 2015), where the student is required to apply knowledge through using the new skill.

2.5 Theorising Learning

The conceptualisation and design of e-learning environments needs grounding in sound pedagogical practice (Mishra, 2001). In other words, integrating pedagogy and learning models within the appropriate technology is essential to make e-learning successful (Nyang'or, et al., 2013). This critical issue of including learning theories in e-learning design has been noted in the literature (Klement & Dostál, 2016; Kothari, 2004; Stoltenkamp et al., 2017). This study noted that using an e-learning environment can contribute to but cannot deliver learning (Dabbagh, 2005). Therefore, e-learning interventions can and must be (at least partially) based on learning theories, whereby it is essential to explicitly describe how the application of technology will support learning. While e-learning does not have a pedagogy of its own, it draws its strength from the three basic theoretical perspectives on learning: behaviourism, cognitivism and constructivism. Therefore, a review of these three primary learning theories was made. Such a review of learning theories was critical to formulate a foundation upon which this study was grounded, provide a selection of instructional strategies, and allow for reliable prediction of their effectiveness (Khalil & Elkhider, 2016). Behaviourist, cognitivist, and constructivist theories have contributed in different ways to e-learning design and can be used to develop learning materials for e-learning. For example, behaviourist strategies can be used to teach the facts (what); cognitivist strategies to teach the principles and processes (how); and constructivist strategies to teach real-life and personal applications and contextual learning (Alzaghoul, 2012).

Since this study explores the design and development of an LMS-mediated tutorial that enables students' *deep* and effective engagement in the learning of foundational mathematics, the concept of deep vs surface learning (Marton & Saljo, 1976) fits very firmly with the orientation of this research. Therefore, deep vs surface learning is also discussed. The following subsections briefly review the key tenets of theories that fall into these three broad categories and their implications for e-learning implementation.

2.5.1 Behaviourism

Briefly, the behaviourism theory of learning is most widely attributed to American psychologist and behaviourist scholar Barrhus Frederic Skinner (1938). Behaviourism focuses on the relationship between the environment and behaviour, where learning is seen as the result of connections between environmental stimuli and related responses and where rewards and punishments drive learning motivation (Bransford et al., 2000). The instructional model developed by Gagné, which consists of the nine events mentioned above (see section 2.4.3), is a suitable scaffold for a behaviourist approach to teaching.

The behaviourist approach has been criticised for its inability to account for learning or changes in behaviour that occur in the absence of environmental input by ignoring the presence of internal psychological or mental processes (Zhou & Brown, 2017). Despite this shortcoming, this model has been applied in teaching and learning in a variety of ways; for example, evaluation of instruction (Slam & Salam, 2019), the design of e-tools (Suyono, 2018) and teaching (Selvam , 2012).

The behaviourist approach suggests a structured, deductive approach to e-learning design. Sequences of instructional units should be defined using conditional or unconditional branching to other instructional units and pre-determining choices within the course (Alzaghoul, 2012). It is expected that this will enable the students to rapidly acquire basic concepts, skills, and factual information. Hence, as Alzaghoul (2012) recommends, students should be given clear learning objectives so that they can set expectations and determine for themselves whether they have mastered the lesson's goals. And they must be tested to decide whether or not they have achieved the learning outcome.

2.5.2 Cognitivism

In contrast to behaviourism, cognitivism theorists focus on the relationship between the student and the environment (Kivunja, 2014). Their central argument is that individual students (on their own) think and actively participate in what is happening in order to learn. They argue that the student's current schema needs to be activated so that the student may use prior knowledge to make sense of and organise new information. Cognitivism recognises the importance of individual differences (i.e., learning styles) and of including diverse learning strategies to accommodate those differences (Alzaghoul, 2012). Individual students' current levels of knowledge, experiences, and skills profoundly impact how the students make meaning of the environment and, therefore, what they learn from their interaction with the environment. One instructional model, the Self-Regulated Strategy Development (SRSD), taking a cognitive approach, was presented by Harris and Graham (1999). SRSD comprises the following six stages: 1) develop and activate background skills and knowledge, 2) discuss the strategy, to promote active participation and ownership of the strategy, 3) model the strategy to demonstrate how to learn and illustrate the thought process of a skilled student, 4) memorise the strategy, to know and understand what is involved with each step in the process, 5) support the strategy, to promote a transfer of strategy performance from teacher to student; and 6) observe independent performance, to demonstrate the use of the strategy for improved academic performance.

The cognitivist approach has been criticised for not recognising the social context in which learning occurs. However, the cognitivist approach suggests that e-learning can enhance learning by facilitating all senses, focusing the student's attention by highlighting important and critical information, reasoning each instruction, and matching the student's cognitive level (Alzaghoul, 2012). Hence, as Alzaghoul (2012) recommends;

- e-learning materials should include activities for the different learning and cognitive styles.
- new information should be combined with existing information from long-term memory, using e-tools to activate existing cognitive structures.
- learning content should be chunked to prevent cognitive overload.

2.5.3 Constructivism

Constructivism theories of learning are identified most widely with cognitive psychologists Jean Piaget (1977) and Lev Vygotsky (1978). These theories postulate that students construct knowledge and meaning from their experiences (Kivunja, 2014). In particular, Vygotsky introduced the concept of Zone of Proximal Development (ZPD) to emphasise that there is a gap between what an individual students can achieve on their own and what they can attain when their full potential is enhanced through the support given by a more capable individual. Many instructional models have been developed to scaffold constructivism. Examples include inquiry-based learning, active learning, experiential learning, discovery learning, knowledge building and the 5E instructional model (Jobrack, 2013). Of these, the 5E instructional model postulated that to maximise students' active learning and construction of knowledge, students should be given opportunities to be involved in five essential elements of constructivism, 1) Engage, 2) Explore, 3) Explain, 4) Elaborate and 5) Evaluate.

The constructivist approach has been criticised in that it may promote a teaching style with unguided or minimally guided instructions for students, ignoring the importance and structure of working memory during learning. This may result in students becoming lost and frustrated (Alanazi, 2016). To overcome this challenge, Kivunja (2014) concludes (from a review of the literature on learning theories) that the constructivist approach to learning should be active and build upon previous knowledge, social and personal (Kivunja, 2014).

- Active: the constructivist approach entices the students to actively participate in the learning process, i.e., "knowledge is not passively received but actively built up by the cognising subject" (Jaworski, 2002, p. 16). At the same time, instructors create environments to help students to learn deeply and to engage with real-world problems. The strength of this approach is that material, content, and learning are related to the students and their situation.
- Build upon previous knowledge: the constructivist approach recognises that students are not empty vessels; they always approach new concepts in the context of previous ideas. Learning is more extensive and deeper when they have opportunities to reflect on what they know, challenge misconceptions, and improve their developing knowledge. Talking to others and engaging in reflective activities can help them to test and compare their current ideas against new ones.
- Social: the constructivist approach acknowledges that learning is enhanced when it is more like a team effort, collaborative and social, not competitive and isolated. Thinking and comprehension are improved when ideas are shared, and responses are given to others. Additionally, students need to feel connected and supported to avoid frustration when encountering difficulties (Engelbrecht & Harding, 2005).
- Personal: the constructivist approach concedes that all students are different; they approach knowledge by bringing their previous experiences, their interests, their values, and a particular style.

The constructivist approach suggests that e-learning can support students' active learning by carrying out high-level activities such as applying the information in practical situations, facilitating the personal interpretation of learning content, or discussing topics within a group

(Alzaghoul, 2012) or involving students in writing, interaction, and problem-solving, relating the learning materials to their worldview (Arendt & Westover, 2014).

2.5.4 Deep vs Surface Learning

Marton and Saljo (1976) introduced the idea of deep learning based on observations of students' approaches when given an essay to read and told that they would be asked questions on it. Two types of students' approaches to this task were observed. Some students focused on the meaning that the essay was trying to convey and tried to understand it thoroughly. Others focused on fragments of information that seemed likely to appear in the test and tried to memorise them verbatim. The former approach was referred to as the "deep approach" and the latter as the "surface approach". Deep learning implies demonstrating higher-order thinking skills such as synthesis and evaluation and a personal commitment to learning the material, not merely learning for the sake of a passing grade. Surface learning, on the other hand, is related more to rote learning and the desire to earn a passing grade (Matsushita, 2018).

Entwistle (2009) argues that the intention for deep learning is to understand ideas for yourself by 1) relating concepts to previous knowledge and experience, 2) looking for patterns and their underlying principles, 3) evaluating the evidence and drawing conclusions from it, 4) examining logic and argument cautiously and critically, and 5) using rote learning where necessary. This results in awareness of one's understanding as it develops and becoming more actively interested in the topic. For surface learning, the intention is to cope with topic requirements by 1) treating the course as unrelated bits of knowledge, 2) routinely memorising facts or carrying out set procedures, and 3) studying without reflecting on either purpose or strategy. This results in difficulty making sense of new ideas, seeing little value or meaning in the courses or the tasks set, and feeling undue pressure and worry about work (Entwistle, 2009, p. 36).

The discussion above suggested that students who employ the deep learning approach are likely to be more engaged with learning tasks than those who use surface learning. This implies that e-learning needs to promote deep learning and not surface learning. This study looks at the role of Web 2.0 technologies (e.g., LMS) in promoting deep learning through in self-regulated learning (Kitsantas & Dabbagh, 2011).

2.5.5 More Recent Development: 2010 onwards

Ertmer and Newby (2013) pointed out the tremendous changes over the last 20 years that have impacted the learning process, i.e., tools have changed, learners have changed, and teaching methods have changed. However, despite these tremendous changes, the underlying principles of learning theories remain relevant.

Still, learning takes place through stimulus-response associations (such as game-based learning), practice and feedback opportunities (as in computer simulations), as well as the processes of collaboration and social negotiation (as in collaborative wiki writing). Although learning situations have evolved from fixed, formal settings to mobile, informal ones, Ertmer and Newby (2013) argue that understanding is still being constructed in ways similar to the past, only with more opportunities to do so now that learning contexts have changed from fixed, formal settings to mobile, informal ones and the tools used to facilitate knowledge (Ertmer & Newby, 2013) construction have also changed from individual, analogue tools to social, digital ones.

Recent opportunities to construct knowledge, explored by researchers, include (among others) 1) written externalisation, 2) social interaction, 3) verbal communication (face-to-face talk) and 4) assessment for and as learning. In this study, these parameters set the foundation for exploring the possible influence of these opportunities on student engagement in online environments generally and the LMS-mediated tutorial specifically.

1) Written externalisation

The issue of written externalisation is part of the more general issue of getting students to generate representations of concepts, processes, and topics for themselves (to develop understandings) or for the teacher (for assessment) (Carolan et al., 2008).

The importance of students generating representations for themselves is that it happens simultaneously with the thinking processes, reveals the solution procedures, and discloses the cognitive evidence included in this process (Mastrothanasis et al., 2018) When generating representations (e.g., writing), students create external structure when thinking, which is simpler to process, more effective, and more efficient than working solely in one's head (Kirsch, 2010).

Student's representations can function as exploratory tools for initial thinking, scaffolding for building understanding, and records of new thinking and reasoning, depending on the purpose or purposes of the representation (Carolan et al., 2008) and to make connections with prior knowledge (Akaygun & Jones, 2013). In other words, they can assist students in becoming active learners, not just consumers of knowledge (Farrokhnia et al., 2020).

Students' representations provide evidence of the thinking process used by the students. In this regard, Farrokhnia et al. (2020) concluded from previous studies that students-generated representations are also helpful for the teacher in many ways. For example, student-generated representations can be used as feedback about students' understanding, to evaluate students' understanding of concepts or to identify conflicts among their ideas.

Students can generate their own representations variety of methods, such as writing, typing, sketches, animations and simulations (Farrokhnia et al., 2020). In this regard, there are many benefits that e-learning can and does offer through e-learning tools. For example, in writing/typing, spell-check and grammar-check tools help improve students writing quality and minimise the teacher's effort on feedback (Balida & Encarnacion, 2020). Other benefits of e-learning tools include using ICT to create representation in various formats, for example, text, audio, video, graphics, images, webinars or podcasts. This is important to accommodate students' differences (e.g., learning styles) and diversity of learning strategies (Alzaghoul, 2012). The result is improved performance, engagement in school activities, increased motivation, and development of other skills like interpersonal communication (Fernandez et al., 2018). The development of interpersonal communication is essential to learning from social interaction, as discussed below.

While there is growing research interest in and explorations of the conditions under which students' construction of representations promotes learning (Prain & Waldrip, 2006; Waldrip et al., 2010), the challenge (explored in this study) lies in how this can be achieved in online environments such the LMS-mediated tutorial.

2) Social interaction

Social interaction refers to ways in which people act with others (Foster, 2018) or the dynamic process of interdependence between the members of society (Cheng et al., 2019). In educational settings, social interaction refers to the students' interaction behaviour with instructors and other students (Fang et al., 2019). This student's interaction behaviour can be verbal (speech) or non-verbal (such as head nods, facial expressions, gestures, posture, eye movements, and tones of voice) (Argyle, 1972).

Social interaction is a vital and necessary component of learning (Hurst et al., 2013). From observation of children interacting with parents and other adults within the community, Vygotsky (1978) concluded that social interaction is fundamental to developing higher mental functions such as identifying speech patterns, learning a language, and deriving meaning from symbols. As a part of learning, social interaction enables students to become readers, writers, speakers, listeners, and thinkers (Vacca et al., 2011). Through interacting with others, students also learn to organise their thoughts, reflect on their understanding, and find gaps in their reasoning (Okita, 2012). Additionally, it helps students get feedback from their teachers and peers regarding their ideas and performance in course-related activities. It encourages them to engage in active learning (Mansour et al., 2009). In short, socially interactive students are actively involved and engaged learners motivated by sharing ideas and evaluating their performance.

Numerous types of social interaction exist, including planned, spontaneous, virtual, or face-to-face cooperation (Waygood et al., 2017). In these social interactions, students learn through the processes of collaboration and social negotiation (Ertmer & Newby, 2013). In this regard, there are many benefits that e-learning can and does offer through e-learning tools, including the ability to encourage networking, communication, information sharing, knowledge management, the interaction between students, group development, and collaboration, in addition to the flexibility to fit the learning around hectic work schedules (Wong & Jeganathan, 2020). This study explores alternative ways to promote social interaction while students work in an online environment, such as the LMS-mediated tutorial.

3) Verbal communication

Successful social interaction during learning requires the physical proximity of students (their existence in the same space). This enables verbal communication (face-to-face talk) and the ability to use non-verbal communication cues during the interaction process (Mansour et al., 2009). This verbal information is most effective when it is given 'just in time (when students can utilise it) and 'on demand' (when students need it)(Gee, 2005). This is difficult to achieve using conventional e-learning tools (Engelbrecht & Harding, 2005). As a result, current research explores more advanced technologies, such as computer-mediated communication, automated response systems, artificial intelligence, interactive multimedia online and dynamic knowledge databases, which can enhance immediate responsiveness (Taylor, 2002). Others have explored how less advanced technologies, such as the synchronous chat feature of LMSs or social media, can support immediate responsiveness (Nelson, 2017). More fundamentally, immediate and individualised learner feedback has been used in tutorial computer-assisted learning (in languages and mathematics) (De Witte et al., 2015; Heift & Hegelheimer, 2017). Alternatively, the computing environment can be used as a catalyst for verbal communication among students by provoking discussions and other learning-focused interactions (Heift & Chapelle, 2012). This study explores how verbal communication can be supported when students are working in an online environment such as the LMS-mediated tutorial.

4) Assessment for and as learning

Assessment for learning (AFL) is an approach to teaching and learning that creates feedback which is then used to improve students' performance (Wiliam, 2011). The purpose of assessment for learning is to inform learning (not to measure it) by focusing on learning as it is taking place, not at the end of a sequence of learning (Heritage & Wylie, 2018). Assessment for learning is concerned with maximising the feedback process (teacher to student and student to teacher) to optimise student learning. This feedback can be a combination of both informal (e.g., oral comments given immediately to learners as they think through problems) and more formal (e.g., written feedback given after an end-of-topic test) comments. Assessment for learning also involves high-quality peer and self-assessment, where learners or peers may be involved in making decisions about future learning needs (Wiliam, 2018).

Assessment for learning supports learning when teachers use the classroom assessment process and the continuous flow of information about student achievement that it provides in order to advance, not merely check on, student learning. In addition, the student engages in actions to improve learning by undertaking the remedial activities provided by the teacher or asking a peer for specific help. This support benefits students by encouraging them to become more involved in the learning process and, from this, gain confidence in what they are expected to learn and to what standard. This can be achieved when students focus on the aim of their learning. This can help them to understand what constitutes 'excellence', take responsibility for their own learning and plan how they might move forward (Wiliam, 2018).

Through continuous feedback information, particularly if it involves feedback from student to teacher, assessment for learning has a positive effect on learner achievement. The teachers use this information from students to effectively modify their teaching (Hattie, 2012).

However, large classes in higher education present difficulties in maintaining a high level of assessment for learning, as envisaged above. For example, Xu and Harfitt (2019) identified challenges around inadequate attention to individual students, reduced opportunities for individualised feedback, overwhelming marking responsibilities, and involving students in assessment. These challenges hindered the teacher's ability to monitor student progress and to collect learning data necessary for subsequent instruction and feedback actions. Current trends in the implementation of assessment for learning tend towards the feasibility of using e-learning to ease these challenges (Xu & Harfitt , 2019).

2.6 Student engagement

Student engagement is crucial for student learning, particularly in the online setting, where students frequently experience isolation and a sense of disconnection (Dixson, 2015, p. 15). Therefore, there are several reasons why it is important to assess student engagement with e-tutorial (Fredricks, 2014). The first is to identify students who are struggling in order to provide better support to these students. The second reason to assess engagement is to monitor how students respond to the e-tutorial activities to see what is working and what might need to be changed. Finally, to collect data on engagement which can be used to evaluate the effectiveness of the e-tutorial. This section aims to operationalise student engagement in order to determine

the possible source(s) of this engagement and describe possible indicators. The focus is on how student engagement can be enhanced by online environments such as LMS-mediated tutorial.
There are many variations in the definitions and measures of student engagement (Fredricks & McColskey, 2012). As Matsushita (2018) noted, student engagement means engagement not only in regular classes but also in co-curricular and extra-curricular opportunities for learning within and outside of the classroom. However, in this study, the focus is particularly on the LMS-mediated tutorial. As a result, the particular definition of engagement must be clarified here. In this study, student engagement is defined as the student's active participation in the learning process (see section 1.3.2). In the most basic sense, engagement is about doing (Bryson, 2014; Healey, 2015). Such a definition is important because it recognises student engagement as getting stuck into doing something (a task), whatever that is. When we engage in a task (even something like cooking or digging) in order to complete it, we learn from this participation through appropriation and then internalisation of our actions (Vygotsky, 1978). We learn from tasks even if our primary aim is not learning. And if we want to learn to do something (e.g., doing mathematics), then we need to be able to focus on doing it just as much as on learning it.
Although several categories of engagement can be identified (Taylor & Parsons, 2011), in this study, engagement is conceptualised as a multidimensional construct based on the three widely accepted in educational settings: cognitive, behavioural and affective (Bond & Bedenlier, 2019; Chapman, 2003; Henrie et al., 2015).

2.6.1 Cognitive Engagement

Cognitive engagement is a measure of investment in intellectual tasks (Chapman, 2003). How much mental effort students put into the learning tasks they are faced with (e.g., effort to integrate new material with previous knowledge) as well as monitoring and using cognitive and metacognitive strategies to understand the task (Chapman, 2003), including flexibility in problem solving, industry and resilience (Chapman, 2003), including flexibility in problem solving, industry and resilience. Cognitive engagement can be considered to embrace how students do tasks (e.g., being able to work out, possible by comparing with a mental picture of the prototype triangle, which trigonometric ratio to work out the length of the side of a triangle). That is, attend to information, store information in memory, access knowledge and use that knowledge to solve problems (Taylor & Parsons, 2011).
Cognitive engagement is a multifaceted construct that encompasses a variety of dimensions, including content engagement, critical engagement, task engagement, self-engagement, and substantive engagement.

1. Content engagement refers to cognitive interaction (i.e., access and review) by the student with appropriately challenging subject matter (McLaughlin, et al., 2005).
2. Critical engagement refers to a process of approaching course materials in a questioning fashion, asking whether course ideas or theories are relevant and valuable (Kigundu, 2014).
3. Task engagement is an effortful striving towards task goals (Fairclough & Venables, 2005) that involves behaviours focused on a particular goal, e.g., attending, recalling, collecting, comprehending, quantifying, planning, and generalising (Gettinger, 1984).
4. Self-engagement is anintrinsically motivated engagement out of curiosity, interest, enjoyment, or to achieve their own intellectual or personal goals (Dev, 1997).
5. Substantive engagement involves sustained commitment to the content and issues of academic study (Nystrand & Gamoran, 1991). Features of substantively engaging instruction include sustained mental concentration, focus, and habits of thoughtfulness.

This study identifies content and task engagement as indicators of cognitive engagement, in an LMS-mediated tutorial, because of their observable actions.

2.6.2 Behavioural Engagement

Behavioural engagement measures the extent to which students actively respond to the learning tasks presented (Bråten et al., 2018; Chapman, 2003). It can be identified in three ways (Bråten et al., 2018; Fielding-Wells & Makar, 2008; Kong et al., 2003).

1. The first is positive conduct, the following of rules and the maintaining of compliant behaviour.
2. The second is active participation in learning activities, identifiable through behaviours that indicate the student is expending effort, diligence, persistence, concentration, attention, completion, questioning, communication etc.
3. Finally, as school commitment identifiable through such measures as school representation in extracurricular activities.

Since doing the LMS-mediated tutorial is a form of learning activity, this study used the second method of identifying behavioural engagement. This form of engagement can be characterised as goal-directed, constructive interaction in the classroom environment (Furrer & Skinner, 2003). It focuses better on *doing a task*, the key aspect of student engagement as defined in this study. In that case, the factors of behavioural engagement were participation (conduct) and performance (outcome) (Dixson, 2015) in the tutorial. As a result, (participation measures) diligence/persistence, concentration and communication, and (performance measures) completion were identified as indicators to provide evidence of behavioural engagement.

However, these terms are not all behaviourally clear and need clarification in terms of specific behavioural (physically noticeable) features. This study measured this type of behavioural engagement as a composite of specific classroom behaviours, such as writing, reading, asking questions, and participating in tasks (Vile Junod et al., 2006). Diligence refers to attempts to do all tasks correctly (Galla, , et al., 2014), concentration refers to focusing on doing the task on hand or staying on-task and not to find other things to do (Berry, 2020) and communication refers to asking the tutor or peers for help (Bond & Bedenlier, 2019). Completion, defined as the successful completion of attempted tasks, was identified as an indirect performance measure of engagement (Henrie et al., 2015).

2.6.3 Affective Engagement

Affective engagement is students' emotional responses to and level of investment in the learning assignments (Chapman, 2003). It can be considered as the beliefs, attitudes, and emotions experienced by students. Aspects of affective engagement have been regarded as enthusiasm, anxiety, interest, boredom, achievement orientation, and frustration (Kong et al., 2003). Affective engagement can be considered as embracing positive and negative reactions to peers, learning, and teachers (Fielding-Wells & Makar, 2008).

Dimensions of affective engagement include, among others, confidence, enjoyment, enthusiasm, excitement, interest, and satisfaction.

1. Confidence: Trust in one's abilities and qualities. Confident learners believe in themselves and their ability to succeed. They are not afraid to take risks and try new things.
2. Enjoyment: Positive feelings and emotions associated with learning. Enjoying learning means finding it pleasurable and satisfying. Learners who enjoy learning are more likely to be motivated and engaged.
3. Enthusiasm: Strong positive feelings and excitement about learning Enthusiastic learners are eager to learn and participate. They are often passionate about their subject matter and share their enthusiasm with others.
4. Excitement: A feeling of intense anticipation or eagerness. Excited learners are eager to learn and participate. They are often energised and motivated by new challenges.
5. Interest: A positive attitude towards learning. Interested learners are curious about the world around them and want to learn more. They are often motivated by the desire to understand and master new concepts.

6. Satisfaction: A feeling of pleasure or contentment resulting from meeting expectations. Satisfied learners feel that they have accomplished something worthwhile. They are often proud of their work and motivated to continue learning.

This study identifies interest, confidence and satisfaction as indicators of affective engagement because of their observable actions.

2.6.4 Deep Engagement

The main activity in this study was to design and develop an LMS-mediated tutorial, which enables students' deep and effective engagement in learning foundational mathematics, particularly trigonometry. Subsequently, one of the objectives of this study was to collect data on student engagement and use it to evaluate the effectiveness of the e-tutorial. Therefore, it was necessary to consider not only the type of engagement but also the level of engagement that was achievable from the LMS-mediated tutorial (Pellas & Kazanidis, 2015).

Matsushita (2018) identified student engagement as a continuum ranging from non-engagement to surface engagement to deep engagement. Non-engagement is not being active due to the absence of certain conditions (such as computer, literacy skills or writing skills) that can foster various modes of student engagement (Holtham et al., 2012; Yates et al., 2014). Surface engagement is being compliant with the minimal requirements of an activity (Schigur, 2018) due to the use of rote memorisation and rehearsal strategies (Lee, 2013). Deep engagement is being active through full participation and involvement in an activity due to the use of a combination of deeper levels of cognitive strategies such as elaboration, organisation and critical thinking, and metacognitive learning strategies (Lee & Koszalka, 2016). Matsushita (2018) argues that deep engagement is close to what Csikszentmihalyi (1990) refers to as flow. Flow is an optimal human experience that occurs when one is completely involved in an activity that provides a matched balance of high challenges and high skills (Gruner, 2016). Flow states are, therefore, indicators of deep engagement.

This study seeks to identify flow states that the researcher can use as indicators of deep engagement in e-tutorial activities. For this purpose, Csikszentmihalyi (1990) identified eight recognisable characteristics of a person who is in a flow state. The person 1) feels that the task can be completed successfully, 2) concentrates entirely on the activity, 3) is deeply involved in the activity, 4) has a sense of control over the actions necessary to perform the activity, 5) self-awareness disappears, and 6) feels an altered sense of time. The activity has 7) clear goals and 8) provides fast feedback (Annetta, 2010).

The challenge for this study was to develop an LMS-mediated tutorial that effectively generates the above-mentioned student engagement states and to be able to measure/identify the engagement level of students. From the above flow characteristics and literature, the conditions of the flow experience were identified as; 1) clear goals for each stage, 2) immediate feedback to one's action, and 3) a balance between challenges and skills (Csikszentmihalyi, 1997a; Csikszentmihalyi, 1997b). In other words, the challenge should be high but doable (Gee, 2005). Moreover, the performer should have the competencies to gracefully dispatch the challenges (Walker, 2010).

2.6.5 Dimensions and Indicators of Student Engagement

Cognitive, affective, and behavioural engagement can be conceptualised as the dimensions of student engagement (Bond & Bedenlier, 2019; Fredricks & McColskey, 2012). The student's actions in these dimensions can be defined as the source of engagement, and the descriptions of these actions can be used as indicators of student engagement. To operationalise student engagement, measures aligned with the proposed conceptualisation and found in the discussions above (sections 2.6.1, 2.6.2 and 2.6.3) are suggested in Table 2.2 below.

Table 2.2: Indicators of student engagement

Dimensions of Engagement	Goal-Directed Actions	Description: Indicators of student engagement	Source
Cognitive engagement	Access	Open resources in order to review/read content	McLaughlin et al. (2005) Fairclough and Venables (2005) Gettinger (1984)
	Review	Study content in order to refresh knowledge	
	Self-regulate	Use results to evaluate progress.	
	Self-engage	Use knowledge and strategy to complete the activity.	
Behavioural engagement	Diligence	Attempt to do all tasks,	Vile Junod et al. (2006) Galla et al. (2014) Bond and Bedenlier (2019) Henrie et al. (2015)
	Concentration	Stay on-task, focus on tutorial activities	
	Completion	Completion of task	
	Communication	Ask teacher or peers for help.	
Affective engagement	Interest	Positive attitudes towards learning	Chapman (2003) Kong et al. (2003) Fielding-Wells and Makar (2008)
	Confidence	Trust in one's abilities and qualities	
	Satisfaction	Meet expectations	

2.7 Conclusion

As e-learning is gaining weight in South African higher education, previous studies focused on teaching material development while adopting LMS tools to mediate students' engagement in learning is under-researched. To contribute to this gap, this study explored the principles for the design of an LMS-mediated tutorial. Building on the literature presented, this study looked at key strategies to support the investigation of an LMS-mediated tutorial design and development, from developments in mathematical education, e-learning, and instructional and learning design.

The literature revealed that to be competent in mathematics requires, among other things; the acquisition of a mathematical disposition, an integrated and balanced development of all the five strands of mathematical proficiency, and knowledge packages that provide an important pattern for learning and teaching mathematics, and learning that requires a combination of the acquisition and participation approaches in order to take advantage of their strengths and at the same time reduce their respective shortcomings. It was also noted that mathematical engagement is vital to acquiring knowledge and strategies for continued participation in the subject and can be afforded by tasks, questions, and prompts in mathematics. The sequence in the solution of these tasks exposes the nature of mathematical engagement. The modes, attributes, and skills of mathematics engagement can be described as the dimensions of mathematical engagement. The student's actions in these dimensions can be defined as the source of engagement, and the descriptions of these actions are used as indicators of mathematical engagement.

Mathematical engagement requires a broad definition of e-learning, i.e., '*learning that is supported by information and communication technologies*. This broad approach goes beyond using various forms of educational technology and learning, both online and offline, to knowing how to change the purpose of existing technologies so that they can be used in a technology-enhanced way. While e-learning uptake is on the rise, critics question the successes of e-learning which seem to remain within the traditional educational paradigm of knowledge transfer. In the context of an LMS-mediated tutorial, a solution to this problem lies in applying fundamental principles for e-learning implementation by taking e-learning as a tool, which can be used in two major ways:1) the presentation of content and 2) the facilitation of learning processes. However, the choice of e-learning tools should reflect rather than determine the pedagogy of a course. LMS can be used as a centralised e-learning environment from which other e-tools can be launched to provide personalised learning by engaging students in the active acquisition and application of knowledge and providing feedback that allows understanding to grow and evolve.

Therefore, taking cognisance of how students can be engaged with the learning opportunities provided through e-learning is also important. The literature review on instructional design revealed that Merrill's design principles could be used as the guiding criteria for the design of the LMS-mediated tutorial, with Gagne's events as the instructional actions for each principle. Secondly, current instructional design trends (influenced by technology advances in social media, cloud-based services, big data and information processing) suggest the focus of instruction not just on learning outcomes but also on the student's overall experience. This suggests that technology should be used to encourage students to spend time on content engagement, enhance critical appraisal, literature review and encourage ongoing learning. To achieve this objective, the conceptualisation and design of e-learning environments needs to be driven by principles of sound pedagogical practice. Thus, e-learning integration into the educational process has emphasised the following learning approaches Behaviourism, Cognitivism, Connectivism and Constructivism. Learning should be active, build upon previous knowledge, be social and personal, and use exogenous tools such as writing and verbal communication.

To evaluate engagement, the three most common in educational settings, cognitive, affective and behavioural, should be considered and used to describe the dimensions of student engagement. The student's actions in these dimensions can be defined as the source of engagement, and the descriptions of these actions used as indicators of student engagement. Student engagement is understood as a continuum ranging from non-engagement to surface engagement to deep engagement, which is close to "flow". Flow states can therefore be good indicators of deep engagement.

3 ANALYTICAL FRAMEWORK

This chapter engages with the development of an analytical framework and tools which can be used to evaluate the design and development of the LMS-mediated tutorial that enables students to have deep and effective engagement in the learning of foundational mathematics, in particular in trigonometry. This process is guided by the following questions, which followed from the main research question (section 1.5) and were used to make sense of the results.

1. What is the quality of the student learning afforded by the e-tutorial system?

This question refers to the effectiveness of the e-tutorial or the extent to which objectives are achieved, particularly what students could do due to their engagement in the learning process.

2. How does the e-tutorial system design affect the engagement process?

This refers to the design of the e-tutorial, particularly how e-tutorial tools facilitate or constrain the engagement process and the role of these tools in resolving contradictions/disagreements between different goals.

3. How does the e-tutorial system engage students in the learning process?

This question refers to the students' use of the e-tutorial, particularly the success and challenges experienced during the process.

4. What principles about learning (learning model) may lead to an effective tutorial design for active engagement? (and why?)

The objective of developing an analytical framework was to build conceptual and analytical tools which can be used to operationalise these questions. For this purpose, Activity theory (Kaptelinin, 2013) was used as a lens to:

1) conceptualise the e-tutorial system and develop it as the unit of analysis.
2) define levels of analysis and identify the starting point of analysis
3) identify mediational factors that could affect students' engagement.

3.1 Introduction

Student engagement is a complex process as it occurs internally in the students' minds and externally in the learning environment, influenced by their values and experiences. These values and experiences can reinforce learning or be a source of challenges. Activity theory is a robust framework to capture, explore and analyse this complexity as it addresses practical needs, is adaptable to various situations and has a simple but powerful hierarchy for describing an activity (Kaptelinin, 2017; Nardi, 1996). Activity theory affords a variety of conceptual activities, including abstracting (selecting and ignoring phenomena), explanation (naming concepts that undergird some phenomenon), contextualising (locating phenomena within a broader spatial-temporal whole), and positioning (establishing an investigative approach) (Blayone, 2019). It has the capacity to analyse learning as the result of tool-mediated interactions that take place in the minds of students (Hardman, 2005).

Due to its conceptual richness, Activity theory has been used as an analytical tool in various situations, including education research (Hashim & Jones, 2007). For example, Leier and Cunningham (2016) used Activity theory as an analytical framework for describing the activity of developing and facilitating the use of Facebook in a German language course. In their study, a deductive analysis cycle was applied to the data, with Activity theory elements using Engeström's (1987) model of the subject, object, community, rules, division of labour, tool/artefacts, and outcome (Leier & Cunningham, 2016). Activity theory is also well suited to analyse design processes as it can constructively describe its activity structure and development in its context (Tjahja et al., 2017). This study used Activity theory as a framework for understanding and analysing individual, technological and community factors influencing design and social innovation in three social initiatives in Bangkok, understanding how they work and why they exist and highlighting the influence of the Thai social and cultural context on the role of design in the social innovation process. Similarly, Activity Theory is appropriate for education research. Their research examines the current use of learning technologies in higher education based on the experiences of students and lecturers in their use of technology-based teaching tools.

3.2 A brief overview of Activity Theory

This section provides a brief historical survey of literature on Activity theory (Kaptelinin, 2013, 2017) to provide background for developing this study's conceptual and analytical framework.

The history of activity theory can be represented by four distinct generations (Engeström, 2001; Khayyat, 2016). The first generation was characterised by work on mediation (Vygotsky, 1978); the second expanded the unit of analysis to include social, cultural and historical perspectives (Engeström, 1987; Leont'ev, 1981); the third generation expanded the unit of analysis to have two activity systems (Engeström, 2001) and fourth generation included four extra elements which have an indirect effect on human beings (Khayyat, 2016).

3.2.1 First Generation Activity Theory

The theory of tool mediation (Vygotsky, 1978) is sometimes referred to as first-generation Activity theory, which is defined as "a philosophical and cross-disciplinary framework for studying different forms of human practices as developmental processes" (Kuutti, 1996, p. 25). Artefacts and tools mediate between the user and the world and transform the user's activity upon the world or facilitate, shape and transform mental processes (Kaptelinin, 2017). For example, the development of mathematical reasoning can be viewed as culturally mediated through language and tool use. In other words, tool use is central to the process by which students mathematise their activity (Jones, 1998). It is a process that enables the student to derive meaning from experience through internalisation, which is the underlying learning mechanism. In other words, student learning occurs through their internalisation of the activity. This allows for a more comprehensive and efficient engagement in this activity. It is externalised in the students' changing engagement in the activity (both instrumental and social). The use of e-learning tools aims to enable and support this process.

The unit of analysis in first generation Activity theory is the activity itself (Engeström, 2014), directed at an object or goal and mediated by a tool, artefact or even another person.

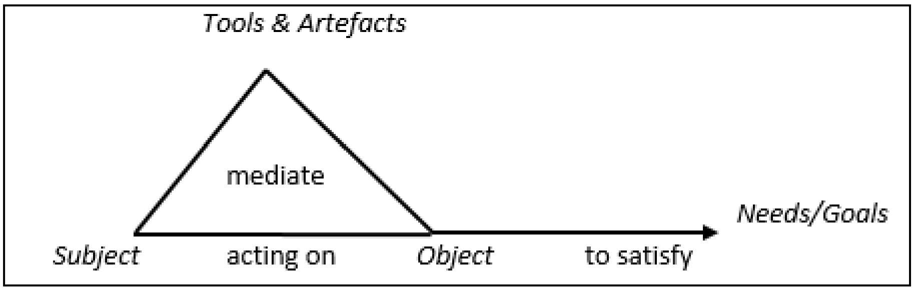


Figure 3.1: Mediated Action (Hashim & Jones, 2007)

The model highlights the idea that the relationship between the Subject and the Object is not direct but mediated through tools (Mwanza, 2001). The subject uses tools to engage in the activity and to accomplish the desired object, thus transforming the material object into an outcome (Kuutti, 1996). This unit of analysis consists of three analytical components, the subject, the object and the mediating tools (Kaptelinin, 2017; Khayyat, 2016).

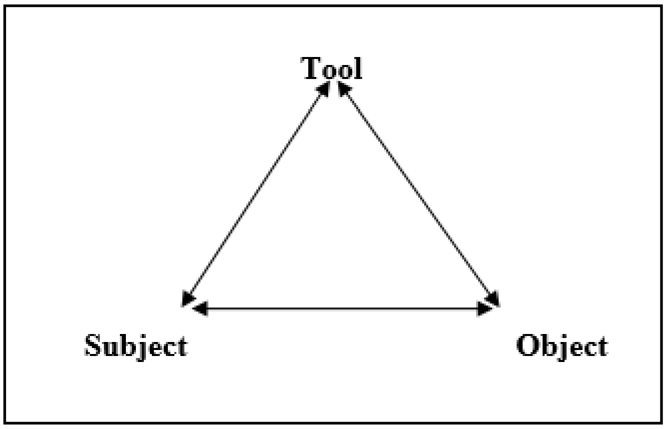


Figure 3.2: First generation Activity Theory (Kaptelinin, 2017)

The subject is the individual(s) involved in the activity. The object is the problem space at which the activity is directed (the primary task of the activity), which can be material (the product of the activity) or ideal (the intent or purpose of the activity) (Hardman, 2007). The tools are the means used by the subject to influence the object. Tools can be categorised as cognitive or psychological (e.g., language, learning strategies) (Vygotsky, 1979), technical (e.g., LMS functions or e-learning tools) (Jonassen & Rohrer-Murphy, 1999) or social (e.g., scaffolding by teachers through feedback (Gorgorió & Planas, 2005).

Vygotsky initiated the fundamental ideas of Activity Theory in his work, which were refined by his colleagues (Kim, 2010). The earliest work to explicitly formulate a theory of activity – hence ‘Activity Theory’ is based on Leont’ev (1978) analysis of the motivated human action structure of activity. Leont’ev (1978) analysis of the motivated human action structure of activity also took into consideration the hierarchical nature of the activity. Leont’ev (1978) distinguishes three different views of active processes carried out by people: 1) object-oriented activity, 2) goal-directed actions, and 3) instrumental conditional operations.

An **activity** is an active process carried out to satisfy some motivating need. The activity is connected with achieving an outcome or goal. The object of an activity is equivalent to a motive because it is associated with achieving the outcome. The objects are transformed into outcomes not at once but through a process that typically consists of several steps or phases (Nardi, 1996). An activity is a natural, concrete activity, not an abstract concept, and is distinguished from other activities by its object. The Activity is always directed towards transforming a specific object, hence the principle of the ‘object-orientedness’ of activity.

The object of activity describes what and why in relation to some phenomenon. Kaptelinin et al. (1999) point out that an object is not restricted merely to “the physical, chemical, and biological properties of entities” (p. 29) but also involves social and cultural aspects as valid objects to be researched (Kaptelinin, 2017). In other words, social interaction and structuring are integral to the activity since the object motive is social, not personal.

An **action** is a process consciously directed towards achieving a practical purpose or goal (Kaptelinin, 2017). Activities are translated into reality through concrete actions, which are conscious steps that contribute to achieving the object of the activity. Actions make sense in that whatever is done to constitute the action aims to achieve the desired goal for the action. The goal is specific, practical, and subsidiary to the activity; thus, it may be quite different from the object of the activity. Actions are implemented through lower-level activity units called operations (Kaptelinin, 2017).

An **operation** is the means by which an action is carried out and how it is done. It is a process in which a person uses a tool to achieve the desired end. Actions consist of chains of operations, which are well-defined habitual (unconscious/automatic, internalised actions) routines used as answers to conditions faced while performing an action. Operations are important for the design of tools to support actions. A tool is a material object that crystallises methods or operations (Leont'ev, 1981).

An action may be viewed as 'what must be done, while the 'operational aspect' is 'how it can be done. However, human activities constantly change and develop. Hence the activity levels are not rigid but dynamic and interactive with one another (Al-Zaydi, 2010).

The components of the activity are summarised in Figure 3.4**.**

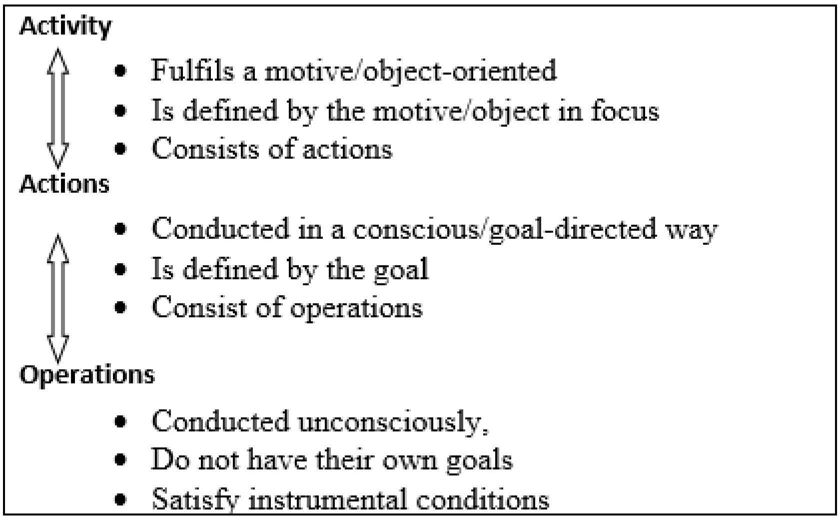


Figure 3.3: Hierarchical structure of activities (Kaptelinin, 2017)

Concerning first-generation activity theory, this study takes note of two ideas. Firstly, the idea that the object of activity may be seen as "objectives that give meaning to what people do"

(Kaptelinin & Nardi, 2006, p. 66). The object of any activity must be considered in at least two aspects (Kaptelinin, 2005): 1) as the relatively direct focus of action and 2) as the motivating force behind this focus. As the relatively direct focus of action, object-orientedness defines the students' goals in a digital learning environment (Owusu-Agyeman & Larbi-Siaw, 2018). As the motivating force behind this focus, object-orientedness portrays the motivation of subjects to interact with particular objects to achieve an outcome (Wiser et al., 2018). This suggests that, in the context of this study, it is essential to understand the objectives of the participants (students) and how they are achieved (Gedera & Sampath, 2014) through the e-tutorial. The researcher can check the effectiveness of the e-tutorial by checking if the objectives are achieved and if the students' objectives align with the learning objectives of the e-tutorial. Therefore, analysis and clarification of objectives are required to understand the process of learning basic trigonometry and how it can be supported by e-tutorial. Secondly, Leont'ev (1978) notion of the hierarchical nature of the activity suggested that considering e-tutorial as a three-layer system provides a possibility for a combined analysis of students' motivational, goal-directed, and operational aspects working in the e-tutorial environment.

3.2.2 Second Generation Activity Theory

The challenge with Vygotsky's basic mediation model is the focus on the notion of mediation explained only in terms of individual actions and not the collective nature of the activity. This challenge was addressed in second-generation activity theory.

Engeström's (1987) modification of Vygotsky's theory introduced the second generation of Activity theory, which considered human activity's social, cultural and historical nature (Khayyat, 2016). Three additional components were therefore introduced to the bottom half of the triangle.

The first is rules, which are the sets of conditions that help to determine how and why individuals may act and result from social, cultural or historical contexts. The rules (explicit or implicit) can be related to legal, moral, ethical, social or cultural considerations. The second is community. This comprises people sharing the same ideal object with the subject but not a material object. People in the community work on different material things to achieve the ideal object or form the product. However, these people can work as part of a community to achieve their objectives. The third is the division of labour, which provides for the distribution of actions and operations among the community. In other words, how the work is divided into tasks, who is responsible for carrying out each task, and how the roles are organised.

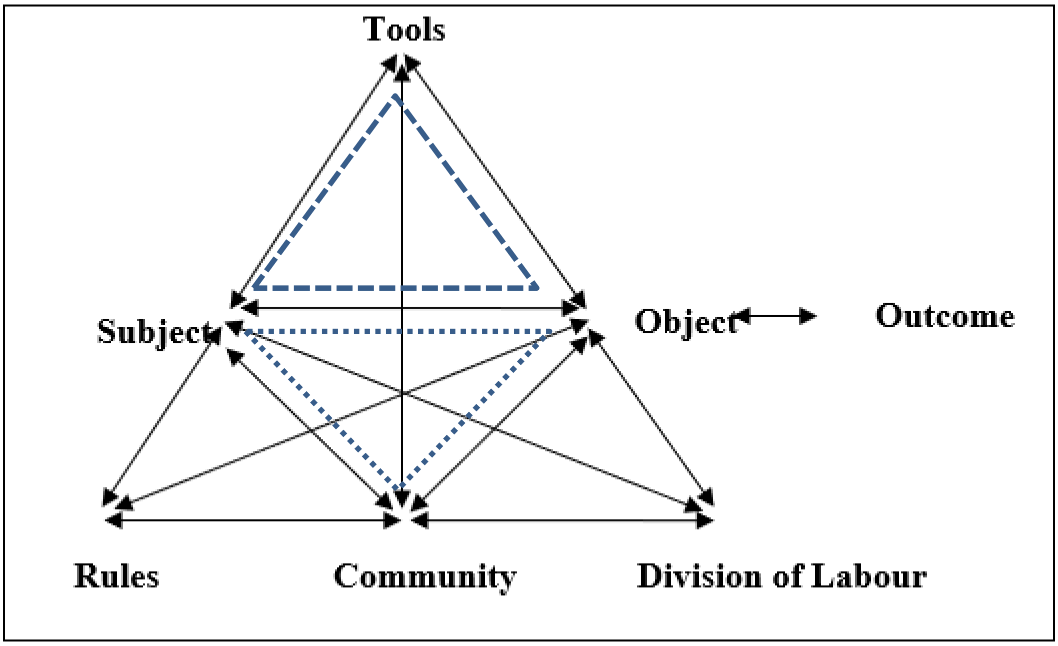


Figure 3.4: Second generation Activity Theory (Kaptelinin, 2017)

Concerning second-generation activity theory, this study notes that Engeström's (1987) activity diagram provided a framework to analyse and describe deep engagement in mathematics activities in the e-tutorial context. The upper triangle, pointing upwards, introduces the goal-directed usage of tools and regulations specifying human activity. Moreover, the inner triangle, pointing downwards, shows how the subject interacts with the environment regulated by rules and supported by the community and the division of labour (Voigt & Swatman, 2005). However, one of the criticisms of activity theory is that it is somewhat abstract when working on a design (Mwanza, 2001). Therefore, this study also attempts to make Activity theory more valuable and practical (Kaptelinin et al., 1999) by developing data collection instruments and analytical tools that assist in clarifying the most critical factors influencing the use of the e-tutorial as a tool to support deep engagement in mathematics activities.

3.2.3 Third Generation Activity theory

Engeström's consideration of the joint (not individual) activity or practice as the unit of analysis for activity theory introduced the third generation of Activity theory (Engeström & Miettinen, 1999). This refers to expanding the unit of analysis from a single activity system to multiple (minimally two) interacting activity systems (Engeström & Glăveanu, 2012) due to the collective nature of human activity (Yamagata-Lynch, 2010). According to Yamagata-Lynch (2010), the third generation of Activity theory was developed for applications of activity systems analysis of situations where the researcher takes a participatory and interventionist role in the participants' activity.

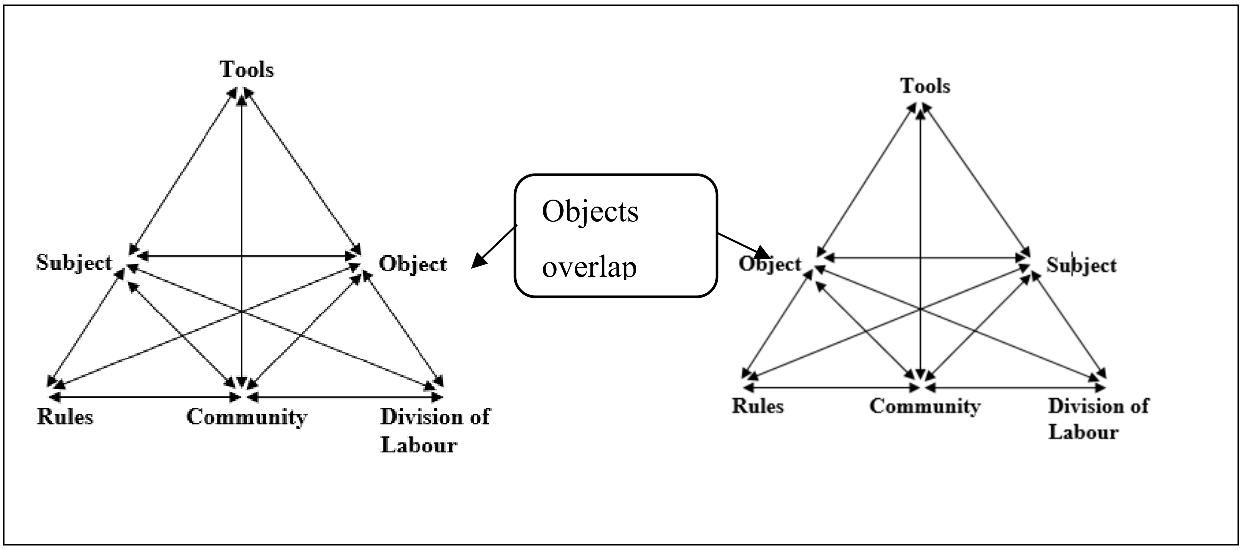


Figure 3.5: Third generation Activity Theory (Khayyat, 2016)

Concerning third-generation activity theory, this study takes note of two ideas. Firstly, the prime unit of analysis is a collective, artefact-mediated and object-orientated activity system, which is to be seen in terms of network relations to other activity systems. Secondly, the objects of the two systems are not fully shared but show some overlap, leading to many contradictions. Contradictions, defined as "historically accumulating structural tensions within and between activity systems" (Engeström, 2001, p. 137), have a central role in providing the catalyst for change and development of the central activity. To attain functional balance, systems need to be assisted in moving through contradiction to consensus (Bloomfield & Nguyen, 2015).

Contradictions have been described as "a misfit within elements, between them, between different activities, or between different developmental phases of a single activity" (Kuutti, 1996, p. 34). Contradictions can be identified at four levels; 1) primary contradictions between actions or sets of actions that realise the activity, found within a single node of an activity, are inner conflicts between an ideal type of work and reality in practice; 2) secondary contradictions arise between the relationships between constituent nodes of activity systems, for example, changed objects or new tools may conflict with an unchanged division of labour or rules; 3) tertiary contradictions between new and old forms in the system, as the conventional activity might continue to be the general practice and 4) quaternary contradictions, occurring between different co-existing or concurrent activities or across an activity network (Engeström, 1987; Engeström, 2001; Uden, 2007).

Contradictions emerge as:

- disturbances in the form of unplanned deviations from the script, which produce disco-ordinations in interaction,

- deviations in the observable flow of interactions,
- disruptions in the processes or activities under observation,
- problems, ruptures, breakdowns or clashes in activities

(Murphy & Manzanares, 2008).

3.2.4 Fourth Generation Activity Theory

Khayyat (2016) introduced the fourth generation of Activity Theory, where he noted that firstly, the catalyst which motivates people to achieve their objectives is absent in the Activity Theory models. Secondly, acknowledgement of barriers and difficulties people may face when conducting any activity is absent. Thirdly, the vagueness of the term object due to an inadequate translation of Leontiev's notion of "object" from Russian to English needs to be clarified. Fourthly, the role of arrows as contradictions or relationships is unclear.

To take care of these issues, Khayyat (2016, pp. 6-7) proposed and justified four extra elements (motivations, barriers, awareness, and environment) in the fourth generation of Activity Theory.

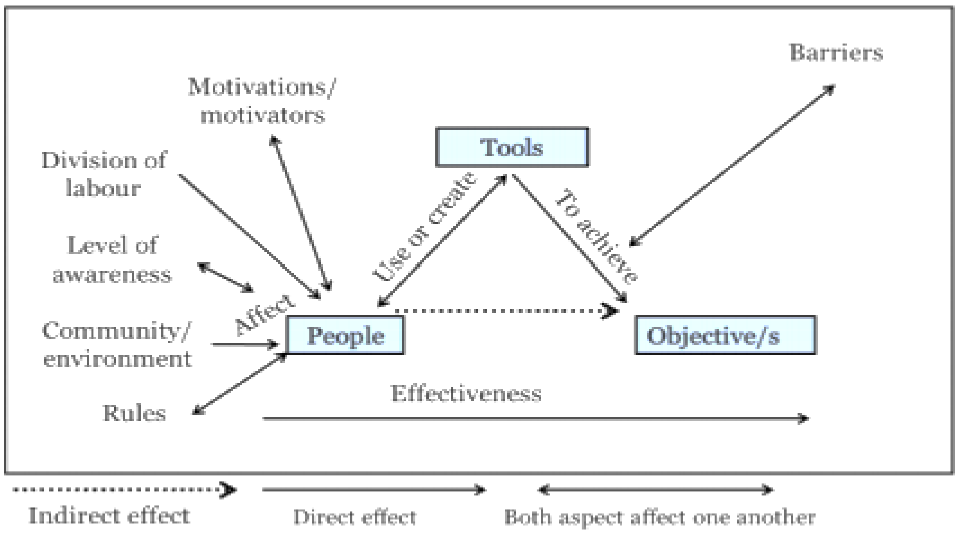


Figure 3.6: Fourth generation Activity Theory (Khayyat, 2016)

In Figure 3.6, Khayyat (2016) shows that in any activity, people need to use mediators or tools to achieve their objectives and outcomes, as Vygotsky (1978) argued. He proposes the following aspects, which have an indirect effect on human beings, should be taken into consideration.

1) Motivations as drivers to achieve objectives.

Within educational contexts, motivation is related to students' needs for and motives for learning activity (Kim, 2010; Markova, 1990). Needs establish the preconditions for a learning activity, and motives are the reasons for doing the learning activity (Kim, 2010). Motivation can be understood as the realisation of motives (Kim, 2010; Markova, 1990). In this realisation, motivation drives individual participation in the activity as the participation results can indicate whether the goal was achieved (Wells, 2011). Therefore, participants (e.g., students) need to understand the activity's motive and value its object. The motivation element should be part of the Activity theory constructs as it is the predominant factor in influencing and driving an individual's goals (Singh, 2011).

2) Level of awareness, of the people (subject), about what they have (in terms of knowledge) and what they can do (skills) element should be part of the Activity theory constructs. These form the foundation of new learning. The key motive for adding Awareness to Activity Theory is that knowledge plays a significant role in each research activity (Khayyat, 2016).

3) Barriers and challenges which may affect the outcomes of the activity. The barriers element should be part of the Activity theory constructs as it may help understand any activity more deeply to provide solutions and recommendations for overcoming the barriers (Khayyat, 2016).

4) Environment in which the activity takes place
The environment element should be part of the Activity theory constructs because the setting and nature in which the activity takes place can directly or indirectly impact the activity of the people due to various influencing forces in the environment.

These new proposed additions to the AT model aimed at opening new avenues, for the researchers, to more helpful elements that can be used in their research inquiry in terms of how they impacted human activities represented by the model.

3.3 Activity Theory ideas incorporated in this study.

In this section, the activity theory's different formulations (generations) are critically discussed in terms of their strengths and weakness in relation to this study. Activity theory is framed by several basic principles which convey some of its complexity in terms of its underpinning psychological processes (Bennett, 2010).

3.3.1 Object-oriented Externalisation Process

The First-generation Activity theory suggests that, in a tool-mediated activity, culturally produced artefacts or tools (e.g., ideas and beliefs, signs and symbols) shape and are shaped by human engagement with the world, which results in learning (as illustrated in Figure 3.7). This process enables the students to derive meaning from experience through internalisation and externalisation, fundamental mechanisms underlying the creation of higher cognitive learning processes (Vygotsky, 1978). Higher mental processes are derived from external actions through internalisation and manifest in external actions performed by a person. Internalisation transforms external activities into internal ones; conversely, externalisation transforms internal activities into external ones (Kaptelinin, 2017).

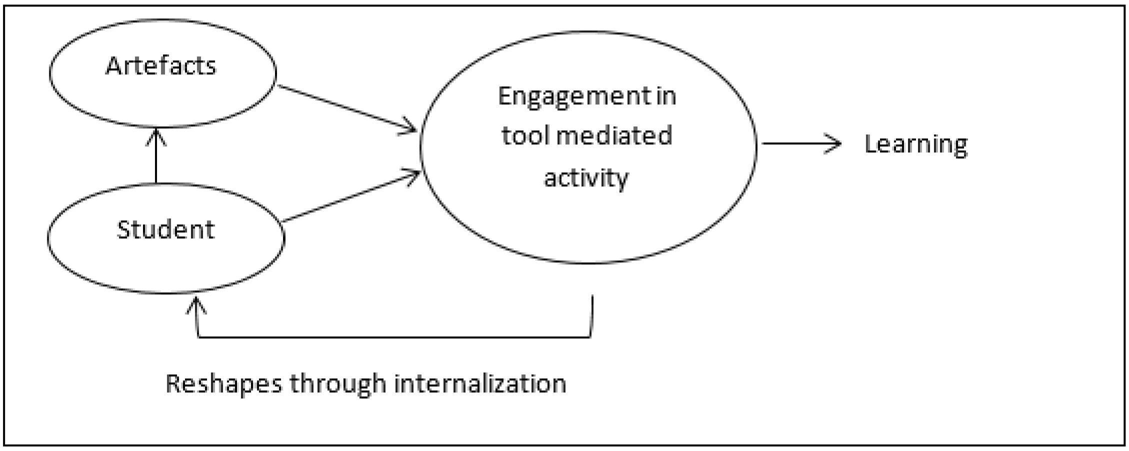


Figure 3.7: The relationship between artefacts, student, engagement and learning

In the context of this study, the computer and e-tutorial provided a means for externalisation. This suggests that consideration of externalisation processes (e.g., tasks) is necessary to verify internalised action and to reveal what needs to be corrected. Externalisation also allows external tools (e.g., pen and paper) to aid thinking by reducing cognitive load and providing external structuring (Kirsch, 2010). Internalising this mediated process results in further mental development (Vygotsky, 1979). The use of e-tutorial aims to enable and support this process.

The First-Generation Activity theory also suggests that activities are coordinated around objects, which are developed when the activities are complete (Kaptelinin, 2013). The objects of activities may be seen as "objectives that give meaning to what people do" (Kaptelinin & Nardi, 2006, p. 66). The researcher can check the effectiveness of the e-tutorial by checking if the objectives are achieved, including difficulties or opportunities that may have altered an activity (Yamanaka, 2015). This suggests that, in the context of this study, it is essential to understand the participants' objectives and how they are achieved (Gedera & Sampath, 2014) through the e-tutorial.

The object of any activity must be considered in at least two aspects (Kaptelinin, 2005): 1) as the relatively direct focus of action and 2) as the motivating force behind this focus. As the relatively direct focus of action, the object defines the subjects' goals in a digital learning environment (Owusu-Agyeman & Larbi-Siaw, 2018). As the motivating force behind this focus, the object portrays the motivation of subjects to interact with particular objects to achieve an outcome (Wiser et al., 2018). Analysis and clarification of objectives were, therefore, a requirement for the understanding process of learning basic trigonometry and how the e-tutorial can support it. Mediation is also a key concept in Activity theory and this study. It describes how activities are mediated by tools and artefacts (tool mediation) (Gedera & Sampath, 2014). Analysis and clarification of e-tutorial tools use can be evaluated in terms of the affordances, difficulties, limitations and frustrations during tool use.

3.3.2 Levels of Analysis: e-tutorial as a three-layer system

In addition, the First-Generation Activity theory suggests that object-oriented activities are composed of goal-directed actions, which are implemented through automatic operations that must be undertaken to fulfil the object (Kaptelinin et al., 1995). Although an activity is much more socially oriented and complex than a task, actions can be considered steps of achieving it, and operations are procedures under each step (Huang & Gartner, 2009). Hence an activity can be analysed at different levels: activities, actions and operations. Consequently, to understand people's behaviour in different situations, it is necessary to consider the status of the conduct in question, whether it is oriented to a motive, a goal, or instrumental conditions (Kaptelinin, 1996).

Taking the students' engagement in the e-tutorial activities as the unit of analysis, the dimensions of engagement (from Section 2.7.5) form the actions layer, as indicated in Table 3.1.

Table 3.1: Levels of analysis

Layer	Engagement
Activity	Engage students in the learning process (of basic trigonometry)
Actions	Dimensions of engagement (from Section 2.7.5) Content engagement, Task engagement, Social engagement, Affective engagement Mathematical engagement
Operations	Students-tutorial interactions For example, Content engagement => access, review, use content Task engagement => be on-task, self-regulate, Social engagement => act with positive conduct, diligence Affective engagement => have confidence, satisfaction Mathematical engagement =>explore and solve mathematical tasks

In the context of this study, considering human activity as a three-layer system provides a possibility for a combined analysis of motivational, goal-directed, and operational aspects of students' working or acting in the e-tutorial environment. This combined analysis can bring together the underlying issues within a consistent conceptual framework. Realising this possibility in a concrete study may be problematic (Kaptelinin, 2017) since it is difficult to reveal the foremost motives of a person or the fine-grain structure of automatic operations. To overcome this limitation of Leont'ev's three-layer model as an analytical tool, Kaptelinin (2017) suggests employing an expansive "actions first" strategy. This strategy involves starting analysis from the actions layer, which relatively easily yields to qualitative research methods.

3.3.3 The nature of the e-tutorial activity: three sub-systems

The Second-generation Activity theory suggests that human activity's social, cultural and historical nature needs to be considered. The mediation concept is extended to include rules (rules mediation) and community (community mediation), which form part of social mediation, an active individual and social process (Gedera, 2016) resulting in the knowledge that is individually, socially, and culturally adaptive (Vygotsky, 1978).

The Second-generation Activity theory recognises subjects' actions mediated by tools, rules, community and division of labour, among other non-human factors (Tjahja et al., 2017). This suggests that, in the context of this study, three sub-systems and three dimensions of mediation, i.e., use, regulation and support, need to be analysed (Ali et al., 2015).

1) The student-tool-object sub-system involves students using the e-tutorial to achieve the objective. This involves tools mediation which may be analysed in terms of the affordances, difficulties, limitations and frustrations during tool use (Gedera & Sampath, 2014).

2) The student-rules-object sub-system involves students' actions *regulated* by rules to achieve the objective. This involves rules mediation which may be analysed in terms of the implicit or explicit rules and regulations (Gedera & Sampath, 2014).

3) The student-community/division of labour-object sub-system involves students' actions *supported* by peers or tutors to achieve the objective. This requires community mediation which may be analysed in terms of peer collaboration and interaction, peer support, and learning from peers (Gedera & Sampath, 2014).

3.3.4 Contradictions analysis and resolution: indicators of the process of e-tutorial development

The Third-generation Activity theory suggests that contradictions, or structural tensions within and between activity systems, have a central role in providing the catalyst for change and development of the central activity. The concept of contradiction is important in activity theory because it provides a simple analytical tool for analysing the contextual design in the activity system under study (Uden, 2007). Contradiction analysis is particularly relevant for addressing inconsistencies between the original designs and conceptions of a learning task and the actual application (Bennett, 2010). Moreover, contradictions are "the motive force of change and development" (Engeström & Miettinen, 1999, p. 9), hence can result in the transformation and improvement of an activity system (Engeström, 2001). Contradiction analysis is an analytical tool for understanding an activity's emerging tensions and transformation (Cui, 2012). Contradiction analysis is particularly relevant for addressing the inconsistency between original designs, conceptions of a learning activity, and actual application (Antoniadou, 2011).

The concept of contradiction is useful in understanding how an activity evolves (Barab et al., 2002). In this study, contradiction analysis was used to identify and explore inconsistencies between the activity's original (anticipated) design objectives and the actual use of the e-tutorial. These were identified as barriers and challenges to achieving the objective, which affected the outcomes of the activity. The resolution of contradictions was viewed as an indicator of the process of development of the e-tutorial system.

3.3.5 Mediational Factors which can have an indirect effect on the activity.

The Fourth-generation Activity theory suggests that four other aspects (motivations, environment, barriers, and awareness), which indirectly affect human beings, need to be considered during the e-tutorial design and development.

The Fourth-generation Activity theory suggests that the motivation element can be used in Activity theory analysis to understand why the subjects carry out the activity (Khayyat, 2016). In keeping with this view, understanding the students' motivations in this study assisted in improvising ways to promote and increase the utilisation of the e-tutorial. Secondly, the e-tutorial environment, as well as functioning as a technical tool, should function as a cognitive tool to provide means to guide and support the student through the use of appropriate interventions such as modelling, coaching and scaffolding by teachers, peers, and educational media (De Corte & Masui, 2008). Mediation of human activity by tool use, which is created and transformed during the development of the activity, influences the nature of external behaviour and the mental functioning of individuals (Kaptelinin, 1996). Hence learning as an active process does not imply that students' construction of knowledge should not be guided and mediated through appropriate interventions (De Corte & Masui, 2008). Unguided instruction is less effective and may result in students acquiring misconceptions and incomplete or disorganised knowledge (Kirschner et al., 2006). Thirdly, barriers which may affect students' use of the e-tutorial to engage in the learning basic trigonometry need to be identified and removed as part of the design-develop process. Any inconsistencies between the original (anticipated) design objectives of the activity and the actual use of the e-tutorial can affect the outcomes of the activity (Khayyat, 2016). Therefore, including the barriers element in Activity theory analysis can help understand e-tutorial activity more deeply to provide solutions and recommendations for overcoming these barriers. Lastly, students' awareness (knowledge) plays a significant role in the e-tutorial. Students' awareness refers to students' understanding of the purpose of the e-tutorial, and the design of the e-tutorial interface for this purpose, so that they know what they are supposed to do (Zurita & Nussbaum, 2007). Therefore understanding the level of students' awareness of the purpose and the design of the e-tutorial allows for the proper support of students' engagement with the e-tutorial activities and can assist in justifying the study's findings as it gives a clearer picture of the research context.

3.4 Activity Theory as an Analytical Tool

The concepts discussed above form the basis for several Activity theory-based tools which can be used to describe, analyse and evaluate the e-tutorial design and development as an activity system (Mwanza, 2002). Activity theory in this study was used both as a descriptive tool for understanding what was happening in the e-tutorial activity system and as a practical tool for guiding its design process to systematically explain and demonstrate how the Activity was happening in a replicable way. For this purpose, this study used the Eight-Step Model (Mwanza, 2002), to identify requirements for the e-tutorial design and development.

3.4.1 The Eight-Step-Model

The Eight-Step Model consists of a series of open-ended questions developed to help researchers translate their data into activity systems components. Each question is matched to a component in the activity system and was designed to help researchers analyse their data specifically from an activity theory framework. The questions identified in the Eight-Step Model are presented below.

Table 3.2: Eight-Step-Model (Mwanza, 2002)

	Identify the AT component	Question to Ask
Step 1	Activity	What sort of activity am I interested in?
Step 2	Object (ive)	Why is the activity taking place?
Step 3	Subjects	Who is involved in carrying out this activity
Step 4	Tools	By what means are the subjects performing this activity?
Step 5	Rules & Regulations	Are there any cultural norms, rules or regulations governing the performance of this activity?
Step 6	Division of labour	Who is responsible for what when carrying out this activity, and how are the roles organised?
Step 7	Community	What is the environment in which this activity is carried out?
Step 8	Outcome	What is the desired outcome of carrying out this activity?

The Eight-Step Model can be used as a heuristic model that captures and unifies activity theory concepts relevant to analysing work practices and learning. For example, Motaung (2008) adapted the Eight-Step Model to develop a classroom observation template that was applied to data gathering during observation sessions. The Eight-Step Model operationalises the components of the activity system triangle into questions (Hill, 2011) which provides a comprehensive framework for gathering data and simplifies the processing of activity theory in the research design process.

Mwanza (2002), however, contends that while this modelling process simplifies the interpretation of collected data, it is still problematic to use for critically analysing learner activities since the information is still too general or abstract (Mwanza, 2002). It is necessary to break down the complex activity system in order to make detailed and significant interpretations possible. In addition, the specialised abstract terminology of Activity theory can be confusing (Gedera, 2016). Therefore, the Activity theory terms were adopted to match this study's objectives and avoid confusion, as discussed in the following section. This involved characterising the e-tutorial learning activity system by answering the open-ended questions in Table 3.3.

3.4.2 The Fourteen-Step-Model

It was also noted that the eight questions were derived directly from the second-generation activity and did not cover some aspects of third-generation theory (i.e., multiple systems, interaction, and contradictions) and fourth-generation activity theory (i.e., awareness, barriers, environment and motivation) as discussed in sections 3.2.3 and 3.2.4 above. Therefore, there was a need to extend the Eight-Step Model to include the issues identified in third and fourth-generation activity theory. Six questions were generated to develop the Eight-Step-Model into the Fourteen-Step-Model as presented below:

1. How many activity systems are involved, what are they, and how do they interact?
2. What levels of contradictions could be expected in this analysis?
3. What is the level of the subjects' awareness about what they have and can do?
4. Where may barriers occur, and how do they affect the outcomes of the activity?
5. What motivations act as drivers to achieve objectives?
6. What is the environment in which the activity takes place?

The resultant Eight-Step Model which include the issues identified in the third and fourth-generation activity theory and the six questions were generated above is presented in Table 3.3 below.

Table 3.3: Fourteen-Step-Model

	Identify the AT component	Question to Ask
Step 1	Activity	What sort of activity am I interested in?
Step 2	Object (ive)	Why is the activity taking place?
Step 3	Subjects	Who is involved in carrying out this activity
Step 4	Tools	By what means are the subjects performing this activity?
Step 5	Rules & Regulations	Are there any cultural norms, rules or regulations governing the performance of this activity?
Step 6	Division of labour	Who is responsible for what when carrying out this activity, and how are the roles organised?
Step 7	Community	What is the community in which this activity is carried out?
Step 8	Outcome	What is the desired outcome of carrying out this activity?
Step 9	Systems	How many activity systems are involved, what are they, and how do they interact?
Step 10	Contradictions	What levels of contradictions could be expected in this analysis?
Step 11	Awareness	What level of awareness, of the subjects, about what they have and what they can do and how does it affect the outcomes of the activity?
Step 12	Barriers	What and where may barriers occur, and how do they affect the outcomes of the activity?
Step 13	Motivators	What motivators act as drivers to achieve objectives, and how do they affect the outcomes of the activity?
Step 14	Environment	What is the environment in which the activity takes place, and how does it affect the outcomes of the activity?

The use of activity theory has generated variously related (analytical sub-) questions that can enrich and expand the primary research questions. This study argues that answers to questions 1 to 8 can be used to characterise the e-tutorial system and specify the analytical context of this study in more detail. In addition, examining the students' engagement with e-tutorial activities, using questions 9 to 14 of this theoretical framework, can provide the researcher with a deeper understanding of *what principles about learning may lead to an effective tutorial design for active engagement. (and why?)*.

3.5 Summary

This study aimed to use Activity theory to examine students' engagement in e-tutorial activities and the mediational factors that affect their engagement. For this purpose, as discussed above, a brief historical survey of literature on four generations of Activity theory was reviewed. It provided the background for developing this study's conceptual and analytical framework.

This review generated five Activity theory ideas which were incorporated in this study: 1) analysis and clarification of objectives (students' goals) as a requirement for the understanding process of learning, 2) levels of analysis, the e-tutorial as a three-layer system, 3) the nature of the e-tutorial activity (three sub-systems), 4) contradictions analysis can be used to identify barriers and challenges to the achievement of the objective, and 5) additional aspects which have an indirect effect on the activity.

An extended Eight-Step-Model (i.e., including third and fourth generation elements) was used to conceptualise the e-tutorial activity system in terms of fourteen Activity theory based elements/ concepts; 1) Activity, 2) Objective, 3) Subjects, 4) Tools, 5) Rules & Regulations, 6) Division of labour, 7) Community, 8) Outcome, 9) Systems, 10) Contradictions, 11) Awareness levels, 12) Barriers, 13) Motivation and 14) Environment.

4 RESEARCH METHODOLOGY

In selecting a research methodology, "it is proper to select that paradigm whose assumptions are best met by the phenomenon being investigated" (Guba, 1981, p. 76). In this study, the choice of research approach followed a logical sequence suggested by (Plomp, 2013, p. 14):

Research question ⟶ **(primary) research function** ⟶ **choice of research design**

The research question (What are the design principles for an LMS-mediated tutorial that enable students' deep and effective engagement in learning foundation trigonometry?) suggested the primary research function was to design and develop a research-based solution for a complex problem in educational practice. The study was exploratory in nature because specific solutions or formulations for addressing the problem were unavailable, and the solution to the problem could lead to the formulation of design principles for similar problems. This suggested that the design research approach would suit this study (Cobb et al., 2016; Kelly, 2013; Plomp, 2013). The methodology, based on the research design approach, is discussed in the following sections.

The structure of this chapter includes five main sections. The first section discusses design research and how it relates to this study. The second provides an overview of the techniques and tools employed in the study. The third section highlights the research design and process used in the study. The fourth section presents the data analysis approach and related procedures, and the last section reports on quality issues and ethical considerations that were considered while conducting the study.

4.1 Educational Design Research

Design research can be defined as "a series of approaches, with the intent of producing new theories, artefacts, and practices that account for and potentially impact learning and teaching in naturalistic settings" (Barab & Squire, 2004; Van den Akker et al., 2006). It is an innovative approach for designing, developing, and evaluating educational interventions appropriate to solve a complex educational problem. It can also advance the researcher's knowledge about these interventions' characteristics and the processes of designing and developing them (Plomp, 2013). Equally significant as the process(es) is the research requirement that the process should produce a set of design principles that identify the characteristics of such a design.

4.1.1 Historical Overview of Educational Design Research

Design research emerged in different places under different names (Prediger et al., 2015). Hence, there are also many other labels to be found in literature, including (but not limited to) the following: Design studies; Design experiments; Development/Developmental research; Formative research; Formative evaluation; Engineering research (Van den Akker et al., 2006).

Design Research is closely linked to Development/Developmental research in educational settings. According to Richey and Nelson (1996), developmental research can offer a systematic study of designing, developing and evaluating instructional programs, processes and products that must meet the criteria of internal consistency and effectiveness (Richey & Nelson, 1996). The focus may vary in emphasis and the extent to which the conclusions are generalisable, resulting in two types of developmental research. Type 1 developmental research demonstrates the design, development, and evaluation processes. In contrast, Type 2 developmental research addresses the design, development, and evaluation process. This study took the form of Type 2 developmental research since one goal is to produce knowledge in the form of new (or enhanced) design principles (Richey & Nelson, 1996).

The Constructivist Teaching Experiment and Realistic Mathematics Education based at the Freudenthal Institute in the Netherlands are two preceding research lines on which design research in mathematics education was built (Cobb et al., 2016). The Constructivist teaching experiment (Steffe, 1983) aimed at enabling researchers to investigate how individual students reorganise their mathematical ways of knowing. The objective was to adapt the constructivist teaching experiment methodology to the classroom setting by creating sets of instructional activities. A limitation of this work was the lack of specific, empirically grounded design heuristics that could inform the development of instructional activities (Cobb et al., 2016). Realistic Mathematics Education complemented the constructivist teaching experiment by concentrating on creating instructional sequences instead of theoretical frameworks to explain the instructional design phenomena. The heuristics for instructional design in mathematics education that they proposed were described by reflecting on the process of designing and improving these specific instructional activities.

The initial focus of Design Research was on supporting and investigating students' learning, although the methodology was later extended to investigate teachers' learning. Two conceptual tools are essential when conducting a design study to explore and support either students' or teachers' learning. These are an interpretive framework for making sense of participants' activity in the complex settings in which design studies are conducted and a set of design heuristics that can guide the development of specific designs (Cobb et al., 2016). The following section describes the design research characteristics used to conduct this study.

4.1.2 Characterising Educational Design Research

The suitability of the Design Research approach for this study was substantiated by the following characteristics of Design Research, described by Van der Akker et al. (2006) and Prediger et al. (2015), and implimented by Pool and Laubscher (2016). These resonate with the objectives of this study. Design research may be characterised as:

1. interventionist, which aims at designing an intervention in the real world. Design research intends to create and study new forms of instruction; in this sense, it must be interventionist rather than naturalistic. The interventionist approach allows for designing a novel intervention, such as the LMS-mediated tutorial.
2. iterative: the research incorporates a cyclic approach to the intervention's design, evaluation, and revision. Design Research involves iterated cycles of prototyping the design, implementation, product development, evaluation, and revision, to refine the effectiveness and practicability of the e-tutorial.
3. process-oriented: the focus is on understanding and improving interventions. The process-focused nature of the research sought to understand both the tutorial development process and the e-tutorial design's effect on the resultant student engagement.
4. utility-oriented: the merit of a design is measured, in part, by its practicality for users in authentic contexts. The utility-oriented characteristic aims to produce knowledge that can be used practically to explain how the LMS-mediated tutorial functions.
5. theory-oriented: the design is based (at least partly) upon theoretical propositions, and field testing of the design contributes to theory building.
6. a theory-driven methodology, design research indicates that the design is predicated on theoretical hypotheses drawn from the corpus of existing knowledge. However, because the research is situated within the real world, the conditions of the study represent the complexity of practice requirements. Hence, research reports also describe those conditions and how they may have influenced the tutorial design and the students' engagement process.

Design research aims to generate theories about the learning process and the means of supporting that learning (Plomp, 2013). Design research can contribute to the more practical relevance of these theories through the progressive approximations of ideal interventions in their target settings, where increasingly workable and effective interventions are constructed, with the improved articulation of principles that underpin their impact. Design research was used to develop an effective LMS-mediated tutorial and offered opportunities to improve understanding of how to design such tutorials.

4.1.3 Educational Design Research approach

The Design Research approach follows an iterative and cyclical process. It moves through three distinct phases: the Preliminary Phase, the Intervention Phase, and the Evaluation Phase (Plomp, 2013; Van den Akker et al., 2006). The Preliminary Phase, as in the case of the present study, involves gathering background information to conceptualise possible tasks, activities, resources, learning tools and electronic tools. The Preliminary Phase aims to formulate a local instruction theory that can be elaborated and refined while conducting the intended design experiment (Gravemeijer & Cobb, 2006). The development and testing of several design prototypes constitute the focal activity of the second phase, which is the Intervention Phase. This is also the main activity of this study, where the research sub-questions are used to guide the development of the e-tutorial. This phase aims to test and improve the conjectured local instruction theory and prototypical intervention developed in the Preliminary Phase and to understand how it works (Gravemeijer & Cobb, 2006). The third phase of the Design Research, the Evaluation Phase, is designated for data analysis and reporting of the study. This phase responds to the main research question. The specific tasks of each phase are proposed in the research design and process (Figure 4.1) and elaborated in Chapter 5.

Due to the many different aspects of what makes for an effective design, multiple ways of looking are required (Collins et al., 2004). This is addressed in Design Research by its flexibility, allowing the methodology to be adjusted to suit the purposes of the research project (Wang & Hannafin, 2005). Hence, mixed qualitative and quantitative methods are essential for the Design Research methodology. The flexibility of Design Research is reflected in the use of various data collection techniques, such as pre-tests and post-tests, surveys and interviews and systematic scoring of observations of the classrooms (Collins et al., 2004). The appropriate techniques and tools used in this study process are more fully discussed and detailed later in Section 4.3.

4.2 Data Collection Techniques and Tools

The Intervention Phase was the main source of data generation. For data generation/collection, Gravemeijer and Cobb (2006) noted that decisions about the types of data that need to be generated in the course of design research depend on the theoretical intent of the study. The data has to make it possible for the researcher to address the issues identified as the theoretical intent at the start of the study. Due to its exploratory nature, this study focussed on developing a local instruction theory in the form of design principles. It made sense to use the following data collection techniques and tools as the main source of data: self-report measures (questionnaire and interviews), observations (direct observation and screen capture videos) and documents (student work samples) (Bakker & Van Eerde, 2015; Gravemeijer & Cobb, 2006; Plomp, 2013). This section provides an overview of these techniques, and the detailed procedures of how these techniques were used are presented in the research design and process (section 4.3).

4.2.1 Self-report Measures

Self-report measures were in the form of students' responses to e-tutorial evaluation questions as answered in questionnaires and interviews.

1) Questionnaires

Questionnaires served as a comprehensive data source from students (Cohen et al., 2007). A questionnaire is a form set up as a list of questions covering a specific part of the study, or the whole study, to provide certain information to a researcher who needs to address a particular problem (Marshall, 2005; Newby, 2014). While questionnaires are at the most structured end of the continuum, they have a place at least in simple, factual information collection (Gillham, 2000, p. 59). For example, questionnaires can gather demographic details, characteristics, and background information about the participant students (Newby, 2014).

The strengths of the questionnaire were one of the reasons why the questionnaire was selected as a research instrument. The following strengths were considered the most important. Carefully planned questionnaires can yield high-quality, usable data and achieve reasonable response rates. Questionnaires provide anonymity, encouraging more honest answers than interviews. This can help to reduce bias. Questionnaires can be given to many students simultaneously, providing greater uniformity as each student responds to the same questions and instructions (Marshall, 2005).

However, using a questionnaire can be problematic due to the following weaknesses. It has limitations in collecting data, such as students typically do not type many words, and some give very short answers for each question, reducing its value. Also, there is no follow-up mechanism, for example, re-checking of responses; if some questions are unanswered, nothing can be done about it (Yang, 2015). Moreover, questionnaires can lead to poor response rates (Cohen et al., 2007). To counter some of these weaknesses, this study used questionnaires to collect only simple, factual information (Newby, 2014). The questionnaires were in an online format in order to ease presentation, collection, and analysis (Lefever et al., 2007).

The questionnaire was used in two ways. First, as a student survey to establish the students' profiles. The student profile included basic demographic information from the student (gender and age), computer use experience and computer accessibility (see Appendix). This student survey aimed to get background information to classify the answers, compare respondents within the group, and ascertain if there were significant differences in their self-perceptions (Cohen et al., 2007). Second, as a learning journal to collect students' reflections about personal experiences as they used the e-tutorial. Learning journals are reflective notes about personal experiences that are recorded over time (Moon, 2010). They help personalise and deepen the quality of learning, assisting students in integrating the learning material, and allowing students to establish an opinion about a topic before being asked to speak about it. Moon (2010) identified eighteen purposes for writing learning journals. Those relevant to this study were recording experience, enhancing problem-solving skills, and facilitating learning from experience. To get students started on their reflective work, several structured questions were given to stimulate reflective writing in the learning journal (see Appendix 8).

Whilst constructing the questionnaire, cautions mentioned in the literature (Cohen et al., 2007; Marshall, 2005) were considered. For example, the questions were mainly opinion and Likert scale types to ease completion. They were written in simple language, clear, understandable style, and free from vague terminology. Items were arranged logically, such as from generalities to specifics. Each one focused on one thing. The items were concise and meaningful and led to definite answers. They were easy to answer and did not force the respondents to think deeply. The items left respondents free to portray their reactions whilst they yielded appropriate information to the researcher. The questionnaire concluded by asking a few open short answer questions to solicit narrative, qualitative information (Marshall, 2005) about students' personal experiences as they used the e-tutorial.
The administration of the questionnaires for data collection is more fully discussed and detailed in section 4.3.

2) Interviews

Interviews were used to get more in-depth and richer informative data about students' experiences as they worked on the e-tutorial. Interviews were in the form of post-tutorial focus group interviews. Focus group interviews have been defined as a group interview, an interaction within the group that discusses a topic supplied by the researcher (Cohen et al., 2007). A focus group discussion-based interview produces a particular type of qualitative data generated via group interaction (Breakwell et al., 2006, p. 276). It is a special type of group in terms of purpose, size, composition, and procedures (Hallas, 2014).

The strengths of the focus group interview are its verbal interaction that gives the interviewees the freedom to answer questions, its systematic method based on a set of steps and procedures governing the meeting, and the scope it provides to conduct the dialogue in the framework of the research objectives (Stewart & Shamdasani, 1990). Compared to traditional interviews, focus groups allow for greater depth of understanding and increased spontaneity because comments from one person may stimulate responses from others (McInerney et al., 2006) and the facilitator can seek clarification in the case of ambiguity (Robinson, 1999). Moreover, the focus group interview is timesaving in terms of setting it up and helps to generate and gather qualitative information at minimum cost (Algahtani, 2011; Gill et al., 2008).

Focus group interviews require skilful facilitation and management by the researcher (Robinson, 1999) in order to limit the effect of the following major challenges. The group dynamics may lead to non-participation by some members and dominance by others (for example, inarticulate members may be denied a voice) (Creswell & Creswell, 2018). In addition, participants' responses are not independent; they are offered in the context of a group's conversation. As a result, participants may respond differently regarding a specific issue (Edmunds, 1999). This can make the analysis of the collected data tedious and complex (Jarrell, 2000). Moreover, the results cannot be generalised as they cannot be regarded as representative of the wider population (Robinson, 1999).

To limit the effect of the major challenges mentioned above, the following precautions were taken; the interviewer endeavoured: to be attentive and sensitive to the interviewees and their feelings, to tolerate silences, to be non-judgemental, and to effectively use prompts, probes, and checks. Interviewers must be sensitive to their effect on the interview; for example, avoid exerting undue influence or pressure on respondents (Cohen et al., 2007). At the heart of the interview sessions was video-stimulated reflective dialogue, in which screen capture videos were shown to the focus groups to stimulate dialogue and discussion (Newby, 2014). These interviews were semi-structured, comprising predetermined questions on the students' teaching and learning needs, the challenges they face and their perceptions, attitudes, and experiences in the e-tutorial. These interviews were "useful for developing themes, topics, and schedules for subsequent e-tutorial development" (Cohen et al., 2007).

The focus group interviews were used in two ways.

1) It was important to identify the current (existing baseline practice) methods, mathematical skills and competencies. This process aimed to identify the basic requirements for the e-tutorial. For this purpose, a semi-structured interview in the form of conversations with mathematics and engineering lecturers was used. Field notes were taken during the process (Cohen et al., 2007).

2) It was also essential to determine the students' teaching and learning needs, the challenges they face and their perceptions, attitudes, and experiences as they used the e-tutorial. For this purpose, semi-structured focus group interviews were guided by an interview schedule (guidelines) with lead questions. Recording equipment was used to ensure the accuracy of the account and to avoid the researcher having to take notes (allowing the researcher to concentrate more fully on the discussion) (Cohen et al., 2007). The recording was later transcribed as a source of data for this process (Collins et al., 2004).

A significant disadvantage of self-report measures is that they are recollections or interpretations rather than records of what happened. Chapman noted that, "although self-report scales are widely used, the validity of data yielded by these measures will vary considerably with students' abilities to accurately assess their cognitions, behaviours, and affective responses" (Chapman, 2003, p. 5). Thus, the onus of understanding students' self-evaluation is often given to external observers, such as teachers or assessors. Observations were therefore used to complement these self-report measures.

4.2.2 Observations

Observations are valuable when collecting information because they can record the dynamics of behaviour and the nature of the environment where the behaviour is taking place (Cohen et al., 2007). The objective is to non–intrusively catch the dynamic nature of events, to see intentionality, and to seek trends and patterns over time (Drury, 1992). In this study, observations took the form of direct observation of students as they worked through the e-tutorial tasks and process videos in the form of screen recordings (screen capture) of student e-tutorial interactions, as explained in the following paragraphs.

1) Direct observation

Direct observation is considered one of the oldest and most fundamental data collection methods (Given, 2008) and one of the most effective ways of collecting ecologically valid data on behaviour (Dishion & Granic, 2004, p. 143). It involves observation of students as they work on the system. The main objective is to note critical incidents or critical events (Cohen et al., 2007) that might typify or illuminate particular features of students' engagement when using the e-tutorial. The data captured during the direct observation was both objective (e.g., the errors students make) and subjective (e.g., any anxiety or frustration).

The major strength of observing is the direct access to the events or interactions which are the focus of the research (Simpson & Tuson, 2003). Consequently, the records are more detailed and direct than data from any other source. Direct observation is useful for looking at resources, identifying problem situations (Slack & Rowley, 2000) and social interactions (Cohen et al., 2007; Simpson & Tuson, 2003). In addition, the researcher has first-hand experience with the participants, records the information as it occurs, and may note unusual aspects. It is also useful in exploring topics that might be difficult for participants to discuss (Creswell & Creswell, 2018). Moreover, direct observation can enrich, and supplement data gathered through other techniques (Cohen et al., 2007; Nock & Kurtz, 2005).

Despite the benefits of direct observation techniques, three main challenges of this approach were noted.

1) The researcher may be intrusive (Creswell & Creswell, 2018). It is tough to conduct unobtrusive observations; the sense of being watched may influence people's actions (Slack & Rowley, 2000). This is sometimes referred to as participants' reactivity to the presence of the observer (Nock & Kurtz, 2005).

2) It is susceptibility to observer bias (Simpson & Tuson, 2003). The researcher may not be good at attending and observing skills resulting in observer drift and perceptual biases of the observer (Nock & Kurtz, 2005) Notes may be selective, subjective and the note keeping may be somewhat random unless the types of actions to be noted are carefully specified in advance (Slack & Rowley, 2000).

3) Cognitive information, such as attitudes, beliefs, motivation, or perceptions, cannot be observed (Slack & Rowley, 2000). Observation does not solely involve watching others; it also involves asking questions to ensure that the interpretation of what is observed is really what is going on (Kawulich, 2012).

To limit the effect of the major challenges mentioned above, the following precautions were taken. To reduce intrusiveness, the researcher was also the facilitator of the e-tutorial sessions and, as a result, was a participant observer of the process (Creswell & Creswell, 2018). One of the main challenges of participant observation was the difficulty of documenting the data. As Mack (2005) noted, it is challenging to record everything significant when participating and observing. Therefore, two tutorial assistants were also employed to assist students with technical or mathematical problems and take note of these problems. Moreover, reliability is enhanced when more than one observer is involved (Nock & Kurtz, 2005). To assess students' attitudes, beliefs, motivation or perceptions, the researcher asked questions to ensure that the interpretation of what is observed is really what is going on (Kawulich, 2012). In addition, observation was also supported by screen recording to provide a closer look at students' actions as they worked.

2) Screen capture video

Screen capture video, made by screen recording software, was employed to capture on-screen activity in a digital video format (Karadag, 2009). Screen capture technology was chosen as a better way to track human-computer interaction, which is difficult to access through direct physical observation of research participants (Imler & Eichelberger, 2011). It is easier to set up than a video camera (Isaías et al., 2014) and can be used without learning interruption, particularly within the education arena (Grushka et al., 2014).

The advantage of this software is that it runs in the background and thus provides the potential for capturing second-by-second detail of student-computer interaction unobtrusively and can support the collection of data in chronological order while capturing learning processes (Grushka et al., 2014). This spontaneous recording of the students' activities provided rich data on how students used the e-tutorial (Imler & Eichelberger, 2011). The quality of the video data of the participants interacting with the software is good (Hosein et al., 2007), this enabled screen-captured videos to be used to stimulate recall during interviews (Brick & Holmes, 2008).

Despite the above advantages of using screen-captured videos, two main challenges of this approach were noted:

1). The captured screen videos have the same colour depth as the screen itself and uses a lot of computer memory. Moreover, the video's huge file size makes it difficult to store (Alexander et al., 2008; Page & Thorsteinsson, 2008).

2) Another of the screen recording method limitations is that it only captures the interactions participants have with their computers and excludes the surrounding context (Alexander et al., 2008; Page & Thorsteinsson, 2008).

To limit the effect of the major challenges mentioned above, only five samples of captured screen videos were kept for transcription and analysis. To cover the surrounding context, the data obtained from direct observation (section 4.2.2) was used.

4.2.3 Documents

For a qualitative study, documents are a good source of text (word) data and (Creswell, 2014) can serve a variety of purposes as part of a research undertaking (Creswell, 2014). Documents provide background and context, additional questions to be asked, supplementary data, a means of tracking change and development, and verification of findings from other data sources. Moreover, documents may be the most effective means of gathering data when events can no longer be observed or when informants have forgotten the details (Bowen, 2009). Documents (e.g., of student work) are generally the most useful for obtaining an objective assessment of what actually takes place in the field (McKenney & Reeves, 2018).

Documents provide the benefit of being in the participants' language and words, who typically pay thoughtful attention to them. Additionally, documents are normally ready for analysis without the necessary transcription that is required with observational or interview data (Creswell, 2014). Documents can be accessed at a time convenient to researcher, unobtrusive and non-reactive in that, they are unaffected by the research process. As written evidence, documents save the researcher the time and expense of transcribing (Creswell & Creswell, 2018). Moreover, Bowen (2009) contends that document analysis is less time-consuming and therefore more efficient than other research methods as it requires data selection, instead of data collection. Documents are stable since the researcher's presence does not alter what is being studied hence documents are suitable for repeated reviews. Documents also provide broad coverage as they may cover a long span of time, many events, and many settings (Bowen, 2009). Despite the above advantages of using documents, two main challenges of this approach were noted.

1) Not all people are equally articulate and perceptive, the documents they produce may contain insufficient detail. Consequently, documents, usually, do not provide sufficient detail to answer a research question. This may be due to materials being not complete or authentic or accurate (Creswell & Creswell, 2018).

2) Another limitation associated with document analysis lies in the difficulty in determining the quality and veracity of the information and data contained in those documents (Ungerleider, 2008).

To limit the effect of the major challenges mentioned above the data obtained from the documents was cross checked and compared with data from interviews (section 4.2.1). Document analysis was used in two ways. First, documents in the form of teaching and learning materials were collected as part of the contextual and mathematical task analysis. Teaching and learning materials involved the student guide, textbook and tutorial sheets. This process aimed to identify the basic requirements for the e-tutorial. These were used to develop course content, resources, and tasks.

Secondly, students' work samples also formed part of the data collection. Students' work samples of rough work were collected, and students answers to e-tutorial questions were also retrieved from the LMS and printed. These documents were used to identify a number of issues, relating to the answering of tutorial questions, which needed to be addressed in the e-tutorial design.

4.2.4 LMS Activity Data

In Design research, assessment may be used formatively in order to dynamically guide the design of a prototype and to inform its iterative re-design as necessary (Kelly et al., 2014). The above qualitative techniques were supplemented by quantitative data, in the form students' formative assessment, which was generated by the LMS. Data in the form of pre and post-test scores was extracted from the grade centre. This quantitative data was used to corroborate the qualitative findings. The LMS Activity data provided the advantage of being automatically generated by the system and was easy to extract from the grade centre of the LMS. In this study the LMS Activity data provided information on 1) Students' work samples, 2) Item analysis, 3) Column Statistics, 4) Attempts statistics, 5) View all attempts and 6) System responses as discussed below.

1) Students' work samples

Student responses (answers) in the activities were accessed via the grade attempt function of the grade centre. From this, a number of issues relating to the answering of tutorial questions were identified. The aim was to investigate how to assist students to resolve these issues.

2) Item analysis

The LMS generated item analysis provided statistics on the overall performance in each activity and individual test questions. This data helped in identifying questions that might be poor discriminators of student performance. The aim was to use this information to improve questions.

3) Column Statistics

The Column Statistics page displays statistics for a grade item, including average, median, standard deviation, status distribution and grades distribution. In this study, the Column Statistics displayed statistics for an Activity, represented by a grade centre column, showing how students fared on each Activity, and how the grades were distributed. The aim was to see Activities in which the targeted pass rated was achieved.

4) Attempts statistics

The Attempts statistics presents information on overall quality of an Activity in terms of score information in the individual questions. For each question in an Activity, score information is categorised as: correct, partially correct, or unanswered. In this study, the summary of attempts statistics presented information on overall quality of an Activity in terms of the quality of the individual questions. The aim was to determine if questions was unclear or were misinterpreted.

5) View all attempts

View all attempts shows all the students' attempts when multiple attempts are allowed. In this study, a summary all attempts presented information on the number of attempts per Activity and the number of attempts in which grades improved, dropped, or remained the same. The aim was to determine whether multiple attempts improved students' performance.

6) System responses

System responses or feedback were afforded by system at the end of each activity. This included correct or wrong answers in each question, overall performance feedback in the form of mark obtained and time spent on each activity. It is important to note here that qualitative research does not only require robust data collection techniques but also the documentation of the research procedure (Bowen, 2009). The research procedures are explained in the following section.

4.3 Research Design and Process

Research design can be thought of as a master plan of the research that explains how the study is to be carried out (Mouton & Marais, 1994). This plan shows how all of the major parts of the research study work together in an attempt to address the research questions (Mouton & Marais, 1994). The research design can be seen as a set of procedures that maximises the data's validity for a particular research problem (Takona, 2002, p. 319). In this study, Design Research methodology (Blessing & Chakrabarti, 2009) was used to merge research and practice while responding to the following research objectives.

1. Study how the students were able to interact with the system (learning to use the system).
2. Study the nature of students learning during the process (effect of the system).
3. Study the effect of the system environment on the learning process (system design).
4. Study the development of the system.
5. Infer design mechanisms that can help instructional designers/lecturers effectively develop a similar system.

The research process incorporated a systematic Educational Design Research approach that followed an iterative and cyclical process. It moved through three distinct phases, namely the Preliminary Phase (prepare for the experiment), the Intervention Phase (test and formatively evaluate in the classroom) and the Evaluation Phase (conduct and document retrospective analyses) (McKenney & Reeves, 2018; Plomp, 2013; Reeves, et al., 2008; Van den Akker, et al., 2006) as demonstrated in Figure 4.1. The Intervention Phase was the main source of data. Testing, evaluation, and review (redesign-develop). Activities were iterated until an appropriate balance between the actual outcomes and the original intended outcomes were achieved. The resultant framework is outlined in Figure 4.1 to provide a schematic overview of the Research Design and Process and the three phases of a Design Research Methodology.

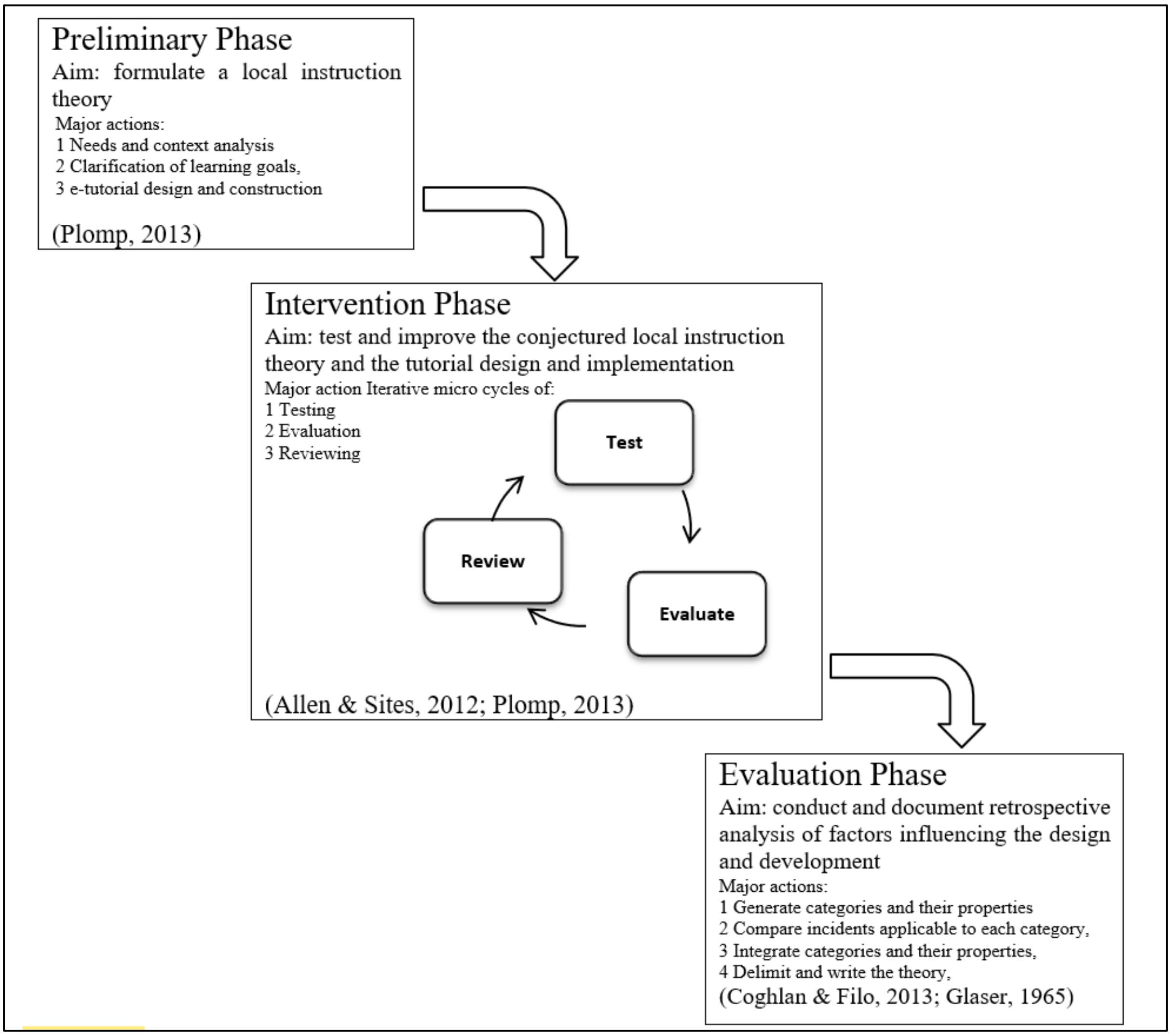


Figure 4.1: Research Design and Process: Three phases of a Design Research Methodology

4.3.1 Preliminary Phase

The objective of the Preliminary phase of a design research project is to formulate a local instruction theory that can be elaborated and refined while conducting the intended design experiment (Gravemeijer & Cobb, 2006). To achieve this objective, the Preliminary Phase was used to specify goals for students' learning, document instructional starting points and describe an envisioned learning trajectory (Plomp, 2013). This process involved 1) target population and sampling, 2) clarification of the mathematical learning goals, and 3) e-tutorial design and construction.

4.3.1.1 Target Population and Sampling

To answer the research questions with the chosen evaluation methods, the required type and number of respondents need to be discussed (Nieveen & Folmer, 2013). This study was conducted as a small-scale research project using convenience sampling (Cohen et al., 2007). The disadvantage of this approach was that no claims could be made in terms of the representability of the outcomes. However, the aim was not to generalise the findings beyond the sample but to use the sample as a test-bed during the design and development of the e-tutorial in response to the main research question. Convenience sampling saved time as the researcher acted as a tutor for this class.

The target population was all the first-year students taking mathematics in the foundation and extended programs in the Faculty of Science, Engineering and Technology (FSET) at WSU. The population included the engineering students enrolled in the Mathematics 1 course. The sample consisted of students from the mechanical engineering department. The detailed descriptions of participants, in the form of the student profiles in each cycle are presented in Chapters 6 and 7. A student profile, which provides information about a student, can be presented and used in different ways. In this study, the student profile included information from the student such as basic demographics, computer literacy and prior mathematical literacy and learning styles. A questionnaire in the form of an on-line learner survey was used in order to ease presentation and collection. From the questionnaire, student profiles were compiled to include a summary of the student's age, gender, matriculation year and clear descriptions of the student's perceived computer literacy levels.

4.3.1.2 Clarification of the mathematical learning goals

A contextual survey was carried out in order to understand the learning context within which the activity of teaching and learning basic trigonometry occured. The two primary goals of the survey were to 1) identify the core ideas in this domain and 2) to formulate a local instruction theory (Gravemeijer & Cobb, 2006).

To identify the core ideas in basic trigonometry required for this course, course handouts, textbook, tests, assignments, examples of mathematics and engineering problems were collected and reviewed. By analysing what doing mathematics entails, the fundamental learning objectives of the basic trigonometry sub-topics were identified. These learning objectives were used to generate focus questions (more details in Chapter 5). The aim and purpose of these questions was to guide the learning process and stimulate students' thinking.

To formulate a local instruction theory, a semi structured interview was used during consultations with mathematics and engineering lecturers to identify the current tutorial format and obtain their views of students' mathematical skills and competency. The aim was to search for existing interventions that could be considered useful examples or sources of inspiration for the conceptualisation of the student learning process in the e-tutorial design. The resultant process model (more details in Chapter 5) was elaborated and refined in the Intervention phase.

4.3.1.3 e-Tutorial system design and construction

In preparation for this study, a basic LMS based tutorial system was designed to engage students in the learning and doing of trigonometry. A module, consisting of course content, resources, and tasks to help the students to explore, practice and apply right triangle concepts, was used to investigate the strategies that can be used.

The initial formulating and design of the tutorial involved; 1) Planning and groundwork to identify the tutorial content, 2) Tutorial design to identify the basic requirements for the tutorial and 3) Tutorial construction to plan how the different e-tutorial components can be put together and be supported by the LMS. This process was guided by Jonassen's (1999) description of essential components in constructivist learning environments (see Section 2.4.4), that is, to design:1) the focus of the environment, 2) related activities, 3) resources, and iv) mediation tools. More details of e-tutorial system design and construction are presented in Chapter 5.

4.3.2 Intervention Phase

The objective of the Intervention phase of a design research project is to test and improve the conjectured local instruction theory and the tutorial design and implementation that was developed in the Preliminary phase, and to develop an understanding of how it works (Gravemeijer & Cobb, 2006). To achieve this objective, the Intervention phase involved iterative micro cycles of design and analysis (Prediger et al., 2015) based on the Successive Approximation Model (SAM) (Allen & Sites, 2012). The Successive Approximation Model was selected because of its fundamental principle that "work progresses in small steps to allow for frequent corrections" (Allen & Sites, 2012, p. 77). This development in small steps, with frequent evaluations, allows for changes that can be changed or reversed at the lowest cost to get a usable product as quickly as possible (Jung, et al., 2019). The progression from cycle to cycle involved the following major steps: testing, evaluation- review and redesign-develop guided by research questions 1, 2 and 3.

4.3.2.1 Testing

The objectives of this stage was the testing of the e-tutorial. This stage involved students doing a series of tasks using the e-tutorial, in the computer laboratory, during the Mathematics tutorial period and the corresponding collection of engagement data.

The students' activities in the e-tutorial were captured using screen capture software (Section 4.2.2). In line with the ethical considerations (see section 4.5.3) students were in control of screen capture software and were encouraged (not forced) to switch it on. This software runs in the background, capturing second-by-second detail of student-computer interactions in an unobtrusive manner (Tang et al., 2006).

All students were encouraged (not forced) to complete a learning journal (Section 4.2.1) detailing their experiences during the tutorial. The learning journal was a structured questionnaire (Kothari, 2004) made up of three parts, aim, directions and questions (see Appendix 8). A mix of 10 closed-ended items and 11 open-ended questions were set. The ten closed questions with options in the form of check boxes constituted the basis and structure of the journal questionnaire (see Appendix 11). The students were asked to choose the appropriate answer by clicking on the corresponding box and could choose more than one box. After each closed question, an open question requiring an explanation of choice, was inserted to provide a more complete picture of the student's feelings and attitudes (Kothari, 2004). This was further supported by two more open questions.

To ease distribution and collection, the questionnaire was set up as a Google form (Vasantha & Harinarayana, 2016). A link to this form was embedded at the end of each activity for students to access the form. After completing the questionnaire, the form was collected when the student clicked on the submit button.

A Google form was chosen as a questionnaire distribution and collection tool because it was a free online, easy to use tool, that enables easy and efficient information collection. This tool provides free, unlimited questions and answers, while other survey tools require a payment depending on the number of questions and recipients. Google form allows the user to see how the survey will look before sending it over to the recipients. Moreover, Google forms store the feedback received and displays a summary of the answers at the same time which makes a detailed analyse easy. The forms are integrated with Google spreadsheets for a more detailed analysis (Negametzyanov et al., 2015).

At the same time, direct observations (Section 4.2.2) of student engagement and interaction were made by the tutor using written notes (Creswell & Creswell, 2018) taken during the tutorial sessions. The focus was on how students engaged with the e-tutorial and the challenges they encountered. The notes, a collection of the researcher's encounters with students who experienced difficulties (Bakker & Van Eerde, 2015), were later transcribed and summarised as shown in Appendix 3.

Stimulated recall interviews using screen capture videos (Dempsey, 2010) were carried out after each cycle. The focus group interviews were used to gain a deeper understanding of students' experiences when using the e-tutorial (Creswell, 2014). A factor that is critical to ensuring significant interaction between focus group members is group composition (Morgan & Hoffman, 2017). Therefore, participant selection was aimed at creating an appropriate heterogeneous focus group to generate differing viewpoints. The number of participants for a focus group was kept between six and ten in order to keep it manageable (Morgan & Hoffman, 2017). This number of participants was large enough to gain various perspectives of the students' experience with the e-tutorial and small enough not to become disorderly or fragmented (Rabiee, 2004). This was achieved by targeting an equal number of weak, average, and good students according to their tutorial performance. Both male and female students were included.

These focus group interviews were semi-structured, comprising predetermined questions which examined the challenges students faced and their perceptions, attitudes, and experiences in the e-tutorial (Cohen et al., 2007). These questions guided and moderated the interview to avoid taking the discussion off target (Morgan & Hoffman, 2017). The interviews were recorded, transcribed, and summarised, as shown in Appendix 4.

In each cycle, students' rough work samples were collected for further analysis of student errors. Also, students' answers to e-tutorial questions were retrieved from the LMS and printed. Student responses (answers) in the activities were accessed via the grade attempt function of the grade centre. From this, several issues relating to answering tutorial questions were identified, for example, students and system errors. Results suggested areas in which corrections and improvements could be made in the e-tutorial.

The last type of data collected was LMS activity data. As the students worked on the e-tutorial, formative assessment data was automatically generated by the LMS and displayed in the grade centre. The grade centre resembles a spreadsheet designed to be used as a grade book. Each row represents a user (student) in the course, and each column includes information for assessment (test) items. The following data sets were extracted from the grade centre of the LMS.

1) Item analysis

The LMS-generated item analysis provided statistics on the overall performance in each activity and individual test questions. The system provided a breakdown of each activity in terms of completed attempts, in progress attempts, average time in each activity, discrimination and difficulty of each question.

2) Attempts statistics

Attempts statistics provided information on how students fared in each question of an activity. The system provided a breakdown of each activity in terms of question, attempts in each question, correct, partially correct answers or unanswered.

3) System responses

System responses in the activities provided information on the system feedback to students at the end of each activity. This included grade (attempt score), status (completed or not completed), time elapsed (in minutes), access log (a break-down of question by question submission) and date activity was done.

A lot of data was generated during testing, in the form of the in-class observations notes, journal questionnaire feedback, interview transcripts, screen capture videos, and system generated data. This data required preparation and organisation to simplify the analysis process. This involved the reduction and presentation of results for each modality as a summary (McKenney & Reeves, 2018). Details of these analysis procedures are discussed in Section 4.4. Outputs of this stage were data that had been organised and categorised, ready for the evaluation-review process.

4.3.2.2 Evaluation

Evaluation and review were two actions that informed the decision process by providing an interim analysis (Gravemeijer & Cobb, 2006) of the data from the testing step. The evaluation provided the "motive force of change and development" (Engeström & Miettinen, 1999, p. 9) and the review provided the direction for transformation and improvement of e-tutorial system (Engeström, 2001).

The evaluation process involved a contradiction analysis (see Section 3.3.3), addressing the inconsistency between original designs and conceptions of the e-tutorial and the actual use during testing (Antoniadou, 2011). This was guided by research questions 1, 2 and 3, as the criteria for evaluation. It involved using different formulations and ideas from Activity theory (section 3.3) to assess:

1) the effectiveness of the e-tuorial activities, to see if the objectives were achieved, by looking at students' performance in terms of tutorial completion rates and pass rates in each activity. (see section 3.3.1),

2) the quality of students' engagement during the e-tutorial by identifying students' success and challenges in the different dimensions of engagement (see Section 2.6.6; section 3.3.2).

3) e-tutorial tools' capacity to accomplish the desired results by looking at how the tools facilitated or constrained the student engagement process (see section 3.3.4).

Details of the analysis procedures are provided in Section 4.4. The evaluation provided the reasons for change and development by identifying redesign issues that emerged from each data modality. The output summarised the critical issues that emerged across the different data sources.

4.3.2.3 Review-Develop

In the review process, this summary of the critical issues was assessed to provide the direction for the transformation and improvement of the e-tutorial system (Engeström, 2001). The objectives of this process were to review the design of the e-tutorial by looking for possible redesign actions needed to address the identified issues through observations of how the intervention was used (Wang, 2013) and the literature review (Oh & Reeves, 2013). It involved:
1) selecting an issue identified for possible improvement in the evaluation process.
2) reviewing the literature to see if there was anything written about such a problem and, at the same time, identify possible solutions to that problem.
3) deciding which strategies to change or add in order to solve that particular problem
Possible, postulated reasons or causes of these issues, together with redesign actions and technology tools, were recorded and added to the evaluation summary to form a review process summary. This was used as a basis for improving the e-tutorial system in the form of re-design ideas used to design the next generation of e-tutorial. The outputs of this review were the possible redesign actions used to redesign-develop the e-tutorial functionality, as discussed in the next section.
The objectives of this stage were to improve the e-tutorial environment in order to provide the functionality required to fit the revised redesign actions. This involved the revision or addition of technological tools. The full details of this process are given in Chapter 5. The output of the redesign was an updated learning environment which was either implemented in the next cycle or evaluated as the final product.

4.3.3 Evaluation Phase

The objective of the Evaluation phase of a design research project is documentation and reflection to produce design principles (Reeves, 2006), by conducting retrospective analysis drawing on the entire data set generated in the Intervention phase (Cobb et al., 2016; Plomp, 2013). The retrospective analysis sought to place the lessons learnt from the Intervention phase in a broader theoretical context by framing them as design principles for the e-tutorial system (Cobb et al., 2016). The focus was to generate, not test, design principles by highlighting the conditions, dimensions, consequences, and processes that surround the data (Coghlan & Filo, 2013). To achieve this objective, the Evaluation phase involved the analysis of the history of design changes, in particular, the main factors influencing the development and the reasons behind these changes, guided by research questions 4 and 5.

Data analysis is a process; therefore, it is often explained or demonstrated as a procedure (Wang, 2016). For that purpose, this study used a framework of four levels/stages of the

Constant Comparative Method (Glaser, 1965) which involved the following significant actions:

1. generate categories and their properties
2. compare incidents applicable to each category.
3. integrate categories and their properties
4. delimit and write the theory

(Coghlan & Filo, 2013; Glaser, 1965; Mansourian, 2006).
Details of the analysis procedures are discussed in Section 4.4.

Outputs of the Evaluation Phase were in the form of knowledge and products. Knowledge claims take the form of design principles or evidence-based heuristics that can inform future development and implementation decisions (Linn, Davis & Bell, 2004; Van den Akker, 1999). Design principles combine substantive (i.e. useful, functional) and procedural (i.e. practical, technical) knowledge with a comprehensive and accurate portrayal of the procedures, results and context, which will enable others to determine relevant insights for their specific settings (Oh & Reeves, 2013).
The product, the practical outputs of design process are also taken as significant outputs (Herrington et al., 2007). The products were design artefacts in the form of the e-tutorial system developed by the researcher. Evaluation of the product's effectiveness was also described (Oh & Reeves, 2013; Wang, 2013).

4.4 Data Analysis Approach and Methods

In Educational design research, data analysis is used to determine if the intervention has been successful; in other words, how close the actual outcomes are to the initial intended results (Plomp, 2013, p. 34). Data analysis enables the researcher to evaluate the effectiveness of the design principles behind the intervention. It also provides "an understanding of the 'how and why' of the functioning of the intervention in the particular context within which it was developed" (Plomp, 2013, pp. 33-34). For this purpose, as McKenney et al. (2006, pp. 85-86) recommend, both inductive and deductive data analysis techniques were used. Inductive data analysis helped in exploring the patterns that emerged from the data. Deductive data analysis helped analyse the data from the perspective of the conceptual framework upon which the intervention is based.

4.4.1 Data Analysis Approach

Due to the iterative nature of Educational design research and the exploratory nature of this study, data analysis was conducted throughout the project's life, not just once towards the end. Using of constant comparisons (Corbin & Strauss, 1990), one round of data analysis conducted during a development cycle helped inform decisions about how to improve the intervention during the next cycle (McKenney et al., 2006). In other words, as discussed in Section 4.3, the research design was not predefined but developmental in response to the ongoing analysis of received data. Moreover, the data collection techniques and tools (discussed in sections 4.2 and 4.3) generated qualitative data from words, observations, and images. Deriving meaning from such data can be a challenging and daunting task. To overcome this challenge, the Framework approach (Ritchie & Spencer, 1994) was used as a means to undertake qualitative data analysis systematically and to ensure that data analysis is explicitly described in order to enhance the credibility of the findings (Smith & Firth, 2011).

A Framework approach is a systematic approach to analysing qualitative data around a theoretical framework (Jones et al., 2007). A qualitative data analysis method offers the research a systematic structure to manage, analyse and identify themes (Hacket & Strickland, 2018). The analytical processes within the framework approach involve a series of interconnected stages that enable the researcher to traverse the data back and forth until a coherent account emerges (Ritchie & Lewis, 2003; Smith & Firth, 2011). The stages provide clear guidance on data analysis from initial collection and management to the development of explanatory accounts (Spenceret al., 2014). The Framework approach enabled an in-depth exploration of the data while maintaining an effective and transparent audit trail to enhance the analytical processes' rigour (Ritchie & Lewis, 2003).

The major strengths of the Framework approach are: 1) The Framework approach is particularly suited to the analysis of cross-sectional descriptive data, enabling different aspects of the phenomena under investigation to be captured. 2) The researchers' interpretations of participants' experiences are transparent. 3) The researcher can explicitly describe the processes that guide the systematic data analysis through descriptive or explanatory accounts (Ritchie & Lewis, 2003).

However, using the Framework approach can sometimes be problematic due to the following challenges: 1) as with all qualitative data analysis, it is time-consuming and resource intensive. 2) making sense of the terminology is challenging. It can confuse the novice due to a lack of agreement in qualitative analysis literature about the use of terms, in particular, 'codes', 'themes' and 'categories' (Spencer et al., 2014). 3). Creating the theoretical framework, constructing the thematic charts, and summarising the data can be complicated, especially if there is any ambiguity in the data (Hacket & Strickland, 2018). To counter these challenges, in this study, the researcher focused on understanding the basic analytical steps or hierarchy, which guided the stages to be followed. Additionally, the Framework approach stages were operationalised using data analysis techniques from Miles and Huberman's (1994) three-step method and Glaser's (1965) constant comparative method. The resultant framework is briefly outlined in Table 4.1 to provide a schematic overview of the analysis, before expanding the details of each component in Section 4.4.2.

Table 4.1: Overview of the Data Analysis Framework

(adapted from Smith and Firth (2011))

Level/Phase	Stages of analysis	Data analysis methods	Actions taken
Level 1 Intervention phase	Familiarisation with the data	Data reduction Data display Conclusion drawing (Miles & Huberman, 1994)	1. Line-by-line searching, analysis and highlighting of phrases in the notes or transcriptions of different data sources. 2. Compilation of highlighted phrases for each data source and present as a data display matrix. 3. Brief discussion of individual elements (emerging from the data) that gave specific insights into student engagement.
Level 2 Evaluation phase	Identify initial categories	Open coding Axial coding (Glaser, 1965)	1 Generate categories of insights and their properties. 2 Compare incidents applicable to each category.
Level 3 Evaluation phase	Infer design principles	Selective coding (Glaser, 1965)	3 Integrate categories and their properties. 4 Delimit and write the theory.

As discussed in Section 4.3, the research design was not strictly predefined but developed in response to the data obtained and ongoing analysis. This resulted in three levels of analysis.

Level 1 took place during the Intervention phase (see section 4.3.2). At this level, the researcher began familiarisation with the data as the mass of data had to be organised and meaningfully reduced in order to be able to draw conclusions about the design and development of the e-tutorial. This was achieved by adopting Miles and Huberman's (1994) framework to carry out data reduction, display, conclusion drawing and verification. The emerging coded categories of concepts of design factors that enabled or constrained students' engagement during the e-tutorial formed the basis for 1) the decisions to adapt the design and implementation during the implementation phase and 2) the answers for research questions one, two and three as described in the findings Chapter 7. This data was further analysed using a constant comparative method (Glaser, 1965) in Level 2.

Level 2 took place during the Evaluation phase (see section 4.3.3). At this level, the researcher identified specific insights into factors that enabled or constrained students' engagement during the e-tutorial, using the summaries generated in Level 1 analysis. The researcher used open axial coding (Holton, 2007) to create categories of these factors and incidents applicable to each category were compared (Glaser, 1965). Categories from this analysis were identified as the basis for the level 3 analysis. These categories helped answer research question four, as described in Chapter 8.

Level 3 formed the second level of data analysis during the Evaluation phase, where the researcher began putting together and interpreting data related to the specific insights into student engagement to integrate categories and their properties, delimit and write the theory. The emerging principles' analysis helped answer the main research question described in Chapter 9.

4.4.2 Data Analysis Methods

Data analysis was primarily an inductive process using a combination of Miles and Huberman's (1994) three-step method and Glaser's (1965) four-step constant comparative method. The detailed procedures of how these methods were used are presented in the following sections.

Miles and Huberman's (1994) Three step method

Miles and Huberman's (1994) three-step method states that qualitative data analysis consists of "three concurrent flows of activity: data reduction, data display, and conclusion drawing/verification" (1994, p. 10).

1) Data reduction

Data reduction refers to the "process of selecting, focusing, simplifying, abstracting, and transforming the data that appear in written-up field notes or transcriptions" (Miles & Huberman, 1994, p. 11). The data need to be condensed for manageability and transformed so that it can be made understandable in terms of the issues being addressed. In this study, the data reduction process focused on extracting what the different data sources suggested about the students' engagement and experience while doing e-tutorial activities. It involved a line-by-line searching, analysis and highlighting of phrases in the notes or transcriptions of all data sources (as discussed in section 4.2). In particular, attention was given to the success and challenges experienced during the process and how e-tutorial tools facilitated or constrained the engagement process.

2) Data display

Data display, the second element in Miles and Huberman's (1994) model of qualitative data analysis, enhances data reduction by providing "an organised, compressed assembly of information that permits conclusion drawing" (Miles & Huberman, 1994, p. 11). In this study, the data display comprised a compilation of the highlighted phrases or information for each data source presented as a data display matrix.

3) Conclusion drawing and verification.

Conclusion drawing involves considering what the analysed data means and assessing its implications for the questions at hand (Frechtling & Sharp, 1997). Verification, on the other hand, involves revisiting the data as frequently as necessary to test and verify the meanings emerging from the data "for their plausibility, sturdiness, confirmability (that is, their validity) (Miles & Huberman, 1994, p. 11). In this study, the conclusion drawing, and verification were in the form of a brief discussion of individual elements in the data that gave specific insights into student engagement. This generated several local themes that emerged from each data modality.

Glaser's (1965) Constant comparison method

Glaser's (1965) constant comparative method was used for the Level 2 and Level 3 analysis of the Evaluation phase of this study. Although often associated with the grounded theory approach, the comparison is also the dominant analysis principle in other qualitative research methods to increase the internal validity of finding (Boeije, 2002). Through this method, findings are founded in the data set, and the identified themes can be illustrated through multiple data fragments, such as quotes (Lincoln & Guba, 1985). Therefore, the constant comparative method was also appropriate for this study because it is highly rigorous and has set stages of coding to guide the researcher to compare and synthesise empirical findings (Leech & Onwuegbuzie, 2007).

Leech and Onwuegbuzie (2007) contend that to perform a constant comparison analysis; 1) the researcher first reads through the entire set or subset of data, 2) then the researcher chunks the data into smaller meaningful parts, which they label with descriptive title or a code 3) each new chunk of data is compared with previous codes and similar chunks labelled with the same code and finally, 4) the codes are grouped by similarity, and themes are identified and documented based on each grouping. Similarly, in this study, a constant comparison was guided by the following major action.

1) Generate categories and their properties

The analysis involved using open coding to search for and identify concepts in the form of common threads that extend throughout the data. This was the initial interpretive process by which raw data was first systematically analysed and categorised (Price, 2010). The objective was to compare different segments of data in order to begin to interpret and explore 1 gradually) the main concern or concerns of the participants, what they viewed as problematic; 2) the tacit assumptions of the participants; 3) explicit processes and actions; and 4) latent processes and patterns (Lapan et al., 2012).

Open coding was useful for Level 2 data analysis to make sense of the Level 1 data as it allowed for comparing information from different data sources (e.g., observation, interviews, journals) (Glaser & Strauss, 2006). In this study, open coding involved a line-by-line analysis (Charmaz, 2008) of information in the local themes that emerged from each data modality generated in Level 1 analysis.

Each local theme item was actively, analytically, and critically read through individually, noting items of interest. At the same time, care was taken to be as inclusive as possible and to be strict about doing this equally for all data items (Braun, & Clarke, 2012). The result was a content-analytic summary of coded categories of local themes; under each category was a description of the constituting subcategories and their properties. This was ready for further exploratory analysis (Miles et al., 2014) as discussed below.

2) Compare incidents applicable to each category

The analysis involved axial coding as a further pass through the data. Axial coding was used to put data back in different ways after open coding by making connections between categories (Kawulich, 2004). The objective was to discover categories that can be combined by identifying dominant concepts and relating them to each other under specific categories and sub-categories in order to establish connections (Corbin & Strauss, 2015). In this study, axial coding involved reading through the summary of coded categories of local themes and identifying codes with similar meanings. Axial coding was helpful in Level 2 data analysis, providing a basis for collecting similar codes, as discussed below.

3) Integrate categories and their properties

The analysis involves selective coding to connect elaborating detailed properties of each category into the significant outline of interrelated categories. Selective coding is the process of choosing and relating the core category to other categories identified during axial coding (Vollstedt & Rezat, 2019). The constant comparative units change from comparing the incident with the incident to the incident with properties of the category, which resulted from the initial comparison of the incident. The objective was to integrate the different categories developed, elaborated, and mutually related during axial coding into one cohesive theory.

Selective coding was helpful in Level 3 data analysis, organising the codes into potential design principles (themes) by reviewing and clustering similar codes. In this study, the thematic analysis approach (Braun, & Clarke, 2012) was used, across data sources and cycles, to analyse and combine categories into themes that described the meaning of the combined categories. The result was a narrative of design principles covering; 1) a conceptually meaningful, clear and concise label developed for each principle (Kawulich, 2004); 2) a statement of each principle; 3) a description of the constituting properties and their characteristics (Boyatzis, 1998).

4) Delimit and write up the theory;
The analysis described above involved taking out irrelevant properties of the categories and integrating details of properties into an outline of interrelated categories (Glaser & Strauss, 2006). The integration resulted in the reduction of the categories to a smaller, higher-level set of principles based on the underlying uniformities in the original set of mechanisms or their properties by which to write the theory, hence, delimiting its terminology and text. This delimiting occurred at two levels. Firstly, the theory, where the delimiting emerged as major modifications become fewer and fewer as one compares the following incidents of a category to its properties. Secondly, the original list of categories was reduced to a smaller set of concepts when underlying uniformities in the initial set of categories were identified. The final action involved the discussion and conclusion of the emergent theory, drawing on the theoretical insights drawn from each category during coding (Coghlan & Filo, 2013; Glaser, 1965; Mansourian, 2006).

4.5 Quality and Ethics

Ensuring that a study's findings can be trusted is a key concern of every researcher. This requires evaluations of the research from the quality and an ethical perspective. This section is divided into two main parts: quality considerations and ethical considerations.

4.5.1 Quality Considerations

This study strived to design a high-quality solution for a complex problem in educational practice (Plomp, 2013). To achieve this objective, the following quality criteria, which apply to a wide array of educational interventions (Nieveen & Folmer, 2013) in Design research, were aimed at:
1) Relevance: There is a need for the basic trigonometry e-tutorial and its design to be based on state-of-the-art scientific knowledge of the learning process.

2) Consistency: This refers to the principle that the basic trigonometry e-tutorial is logically designed, and all the components are appropriately linked together.

3) Practicality: The basic trigonometry e-tutorial is usable in the settings for which it has been designed. Here the expected and actual use is compared.

- Expected: The basic trigonometry e-tutorial is expected to be usable in the setting for which it has been designed.
- Actual: The intervention is usable in the LMS setting for which it has been designed.

4) Effectiveness: The intervention is expected to result in desired outcomes.

- Expected: Using the intervention is expected to fulfil the desired outcomes.
- Actual: Using the product results in desired outcomes as stated in Table 3.2.

The intervention should suffice for all these criteria at the end of a design research study.

In this study, two challenges to the quality of the research were encountered:
1) Design research is conducted in close collaboration with educational practice (Alghamdi & Li, 2013). Therefore, it requires practitioners' involvement and active participation at various stages of the intervention development (Cobb et al., 2016). The challenge was finding further professional scrutiny and critique by people outside the project.

2) The researcher was the designer and also evaluator for the e-tutorial. This created the potential for conflicts of interest since he was intimately involved in the conceptualisation, design, development, testing, and re-searching of the e-tutorial (Alghamdi & Li, 2013). The challenge was to ensure that researcher could make unbiased, credible, and trustworthy assertions about the tutorial quality (Anderson & Shattuck, 2012; Barab & Squire, 2004). To reduce the effect of these challenges, the following mechanisms were used during the research process to ensure reliability and validity incrementally and, thus, the study's rigour (Morse et al., 2002). Mechanisms followed were: 1) methodological coherence, 2) iterative process, 3) appropriate representative sample and 4) theory developed as an outcome of the research process. These are discussed in the following subsections.

4.5.1.1 Methodological coherence

Methodological coherence ensures congruence between the research question and the components of the method (Morse et al., 2002). The objective is to have a good quality research design, where each part of the research design is equally strong. This was achieved by following a systematic Educational Design Research approach. The supervisor was asked to guide and check the validity of the research steps and processing.

4.5.1.2 Iterative process

Qualitative research is iterative rather than linear. A good qualitative researcher moves back and forth between design and implementation to ensure congruence among question formulation, literature, recruitment, data collection strategies, and analysis (Morse et al., 2002). This study used iterative micro cycles of design and analysis to test and improve the conjectured local instruction theory and the tutorial design (see section 4.3). This enabled identifying and correcting errors through systematic documentation, analysis and reflection of the design, development, evaluation and implementation process and results.

4.5.1.3 Appropriate representative sample

An appropriate representative sample consists of participants who best represent or have knowledge of the research topic. This ensures efficient and effective saturation of categories, with optimal quality data and minimum waste (Morse et al., 2002). In this study, the aim was not to generalise the findings beyond the sample but to use the sample as a test-bed during the design and development of the e-tutorial in response to the main research question. Consequently, convenience sampling was used as the researcher acted as a tutor for this class. However, the sample did not effectively cover the student group since it covered only the Mechanical engineering group and excluded the Electrical and Civil engineering groups.

4.5.1.4 Theory is developed as an outcome of the research process,

Theory development is to move with deliberation between a micro perspective of the data and a macro conceptual/theoretical understanding. In this way, a theory is developed through two mechanisms: 1) as an outcome of the research process and 2) as a template for comparison and further development (Morse et al., 2002). In this study, theory development involved a verification process of checking, confirming, making sure, and being certain, guided by a three-level data analysis framework approach (see section 4.4). Data was systematically analysed, supporting interpretations with evidence to ensure that all claims were derived from data and presented in a balanced perspective (Ritchie & Lewis, 2003).

4.5.2 Trustworthiness

Trustworthiness of a study refers to the degree of confidence in data, interpretation, and methods used to ensure the quality of a study (Connelly, 2016). Trustworthiness is a term used in qualitative research to describe methodological rigour (Boyd, 2018; Hays et al., 2016). The purpose of ensuring trustworthiness in qualitative research is to support the argument that the findings merit consideration (Lincoln & Guba, 1985). Lincoln and Guba (1985) contend that the conventional criteria to establish rigour (i.e., reliability and validity) is inappropriate within the qualitative paradigm and that the concepts of credibility, transferability, dependability, and confirmability should be used to determine the value of a qualitative study (Lincoln & Guba, 1985, p. 300). These criteria and how they were established in this study are discussed below.

4.5.2.1 Credibility

The concept of credibility asks whether the study was conducted per the usual procedures for the indicated qualitative approach or whether an adequate justification was provided for variation (Connelly, 2016). Several strategies can be used to enhance the credibility of qualitative research, i.e., member checks, peer review, researcher reflexivity, prolonged engagement, negative case analysis, thick description, external audits, and triangulation (Creswell & Poth, 2016, pp. 207-209; Merriam, 2002, pp. 25-27). As Merriam (2002) claimed, these are not exact prescriptions but can provide a useful reference. However, Creswell (2014, p. 209) recommends using at least two out of the eight (Merriam & Grenier, 2019).

For this study, two strategies were employed: 1) prolonged engagement and 2) triangulation.

4.5.2.2 Prolonged engagement

Prolonged engagement refers to interacting with respondents for an extended period in their native culture and everyday life to better comprehend their behaviour, values, and social relationships in a social context (Merriam, 2002). Prolonged engagement enables the researcher to 'build trust with participants, find gatekeepers to allow access to people and sites, establish rapport so that participants are comfortable disclosing information, and reciprocate by giving back to people being studied' (Creswell & Miller, 2000, p. 128).

In this study, data were collected over four cycles where the researcher was also the facilitator of the e-tutorial sessions. Each cycle lasted four days, and each e-tutorial session took 2 hours as set out on the students' timetable. As a result, the researcher could observe students in class and online activity as they worked on the system. This prolonged engagement greatly enhanced the study's credibility as it offered the opportunity to gather a significant amount of data and increase rapport and trust with the students.

4.5.2.3 Triangulation

Triangulation refers to qualitative research's use of multiple methods and data sources to understand phenomena completely (Carter et al., 2014). The themes and categories can then be created using multiple and different types of data. Using triangulation through various data sources contributes to improved credibility and dependability in the findings of design-based research (Alghamdi & Li, 2013; Sarantakos, 2005). Triangulation of data sources and data collection methods was applied to increase the quality of data. These methods included focus group interviews, questionnaires, direct observation, screen capture videos, students' work samples and LMS Activity data, as discussed in sections 4.2 and 4.3. Time triangulation was achieved through four research process cycles (section 4.3). Triangulating this data created the themes and categories derived as part of this study. Additionally, in the Preliminary Phase of the study, consultations with mathematics and engineering lecturers were carried out to identify the current tutorial format and obtain their views of students' mathematical skills and competency.

4.5.2.4 Transferability

Transferability refers to the extent to which findings are useful to persons in other settings. The objective is to provide a vivid picture of the study through rich, detailed descriptions of the context, location, and people studied and transparency about analysis and trustworthiness (Connelly, 2016).

To enhance the transferability of this research, context descriptions and interpretative commentaries have been provided in the results chapter. Listed in detail are the number of participants involved in a cycle of the research process, the data collection methods employed, and the number and length of the data collection sessions. Moreover, being situated in a real educational context ensured that the results can be effectively used to assess, inform, and improve practice in at least this one (and likely another) context.

4.5.2.5 Dependability

The conventional equivalent of dependability is reliability which is concerned with establishing whether the findings are stable, consistent, predictable, and replicable (Lincoln & Guba, 1985). However, in qualitative research, the concept of reliability is problematic as human behaviour is in a constant state of flux and replication of the study will not provide the same results (Merriam, 2002). In this study, dependability demonstrated that data was not invented, misrepresented, or carelessly recorded or analysed (Mason, 2017).

Dependability was enhanced by outlining transparently the procedures that led to the research findings, describing the strategy of the research design (section 4.1.3) and its implementation (section 4.3), as well as the way data, was gathered (section 4.2).

4.5.2.6 Confirmability

Confirmability is the degree that findings are consistent and can be repeated (Connelly, 2016). This implies that researchers should fully disclose the data they base their interpretations on or make those data available (Heigham & Croker, 2009, p. 215). Confirmability can be improved by precisely recording and keeping all data for additional scrutiny.

Confirmability was established, in this study, by keeping an organised, systemic audit trail of records and a reflexive journal of the research process. Confirmability was improved by utilising several data collection methods, which enabled the triangulation of results. This data is fully disclosed in the appendices. Additionally, through peer review, the supervisor gave the researcher opportunities to reflect upon researcher biases in shaping the research project by challenging and questioning decisions and assumptions taken.

4.5.3 Ethical Considerations

The researcher had to put into practice the University's ethics procedures which the information gathered was treated with confidentiality and anonymity. Thus, ethical approval was obtained before the research commenced. However, interested parties could be presented with the research outcomes.

In light of this requirement, the following actions were taken to ensure the smooth and ethical running of the study.

1) Obtain informed consent

The students and the lecturers were contacted before the data collection process began. Appropriate consent forms and introductory letters that provided details of the research and the data collection procedure were given to the study participants. Their consent was obtained before data collection.

2) Ensure voluntarily participation

Since e-learning in mathematics is presumed beneficial to students, all students were required to attend these tutorials. However, participation in the research, which entailed interviews, questionnaires, journaling, and observation, was voluntary, and students were allowed to decline to participate and withdraw at any time. Those who declined in each data collection mode (questionnaires, journaling, observation) still had access to the tutorial and received equal attention from you as a tutor. So, services were not curtailed to any student even if they were not generating data.

3) Maintain confidentiality and anonymity

The data and personal information collected for this study are kept securely. The data was used for the PhD thesis, journal articles, and conference and seminar presentations. The data will be destroyed after five years. Rhodes University will make the completed PhD thesis available on the internet. Only the researcher and supervisor have access to raw data, and data from this research will not be shared with any other external party for any reason. Participants in this research are anonymous, as no names have been used. Thus, the participants are unlikely to be identified by any references made in the study.

4.6 Summary

This methodology chapter has covered several issues and highlights the complexity of the research process in this study. In this summary, the five key aspects of the methodology for this project are highlighted.

The first section discusses design research and how it relates to this study. The suitability of the Design Research approach for this study was substantiated by the following characteristics of Design research, which resonate with the objectives of this study: interventionist, iterative, process-oriented, utility-oriented, and theory-oriented. The Design Research approach involved three distinct phases, 1) the Preliminary Phase, 2) the Intervention Phase, and 3) the Evaluation Phase.

The second section provided an overview of the data collection techniques and tools employed in the study. Due to its exploratory nature, this study focussed on developing a local instruction theory in the form of design principles. To achieve this objective, it made use of the following data collection techniques and tools: self-report measures (questionnaire and interviews), observations (direct observation and screen capture videos) and documents (student work samples).

The third section highlighted the research design and process (Design Research methodology) used in the study. The research process incorporated a systematic Educational Design Research approach that followed an iterative and cyclical process. It moved through three distinct phases, namely the Preliminary Phase (prepare for the experiment), the Intervention Phase (test and formatively evaluate in the classroom) and the Evaluation Phase (conduct and document retrospective analyses. The Intervention Phase was the primary source of data. Testing, evaluation-review, and redesign-develop activities were iterated until an appropriate balance between the actual and original intended outcomes was achieved.

The fourth section presented the data analysis approach and related procedures. The Framework approach was used to systematically undertake qualitative data analysis and to ensure that data analysis is explicitly described to enhance the credibility of the findings. The Framework approach enabled an in-depth exploration of the data while maintaining an effective and transparent audit trail aimed at improving the rigour of the analytical processes. The framework approach stages were operationalised using data analysis techniques from Miles and Huberman's (1994) three-step method and Glaser's (1965) constant comparative method.

The last section reports on issues of quality, trustworthiness and ethical considerations that were considered while conducting the study.

This study strived to design a high-quality solution for a complex problem in educational practice. The Design research quality criteria aim to achieve this objective by considering relevance, consistency, practicality, and effectiveness.

5 TUTORIAL DESIGN AND DEVELOPMENT

This chapter presents a historical account of the tutorial design and development process. The tutorial items' analytical basis, development and deployment are also discussed. This chapter also explains, with examples, the formulation of and justification for different activities incorporated into the tutorial.

5.1 Application of the Successive Approximation Model

The tutorial development process followed the Successive Approximation Model (SAM) (Allen & Sites, 2012) in order to get a usable product as quickly as possible. The emphasis was on rapid prototyping and getting input from representative users. The development process took place in three phases (Allen & Sites, 2012), as summarised in Figure 5.1.

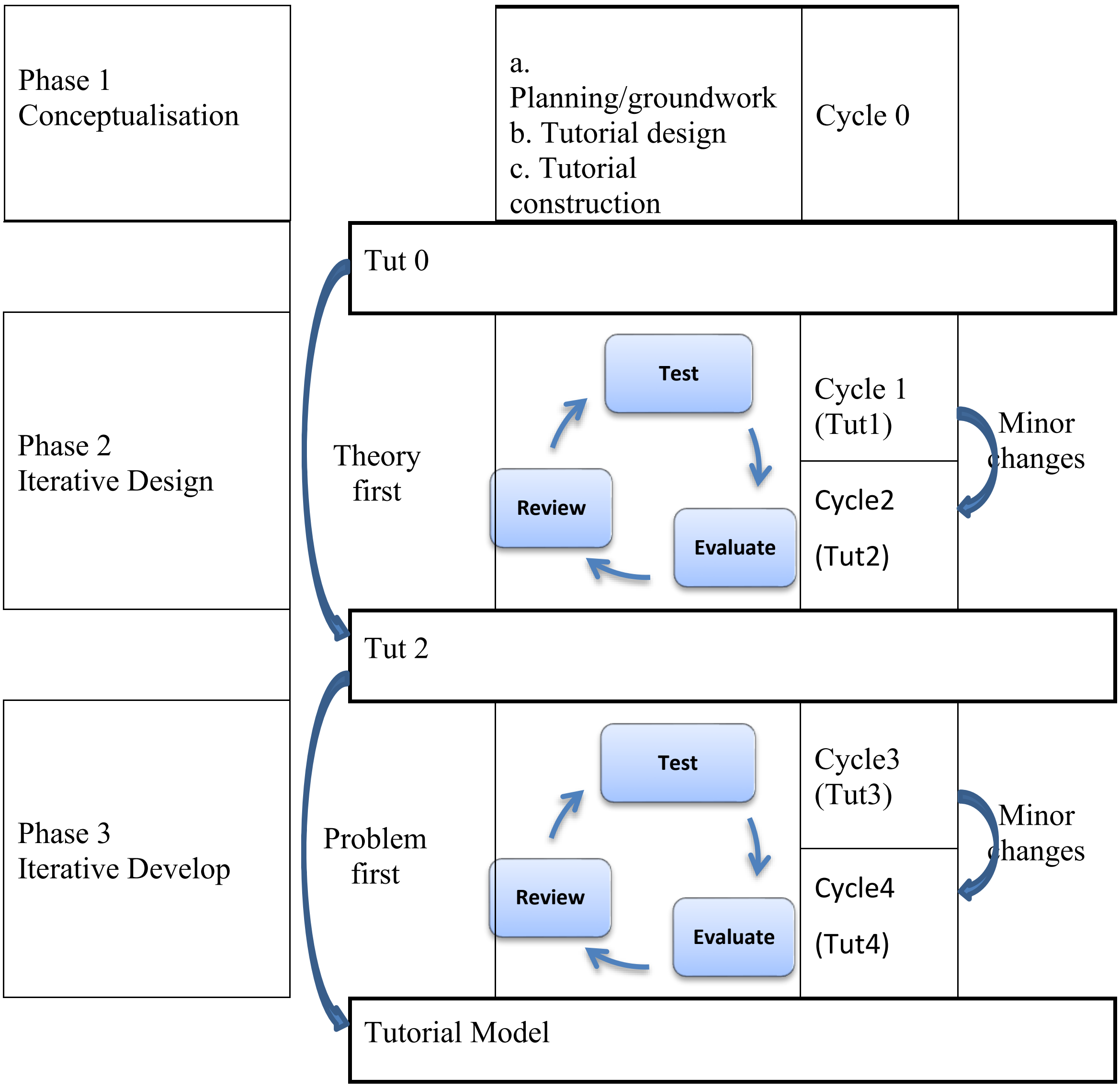


Figure 5.1: SAM (Allen & Sites, 2012)**: Iterative Tutorial Development**

In Phase 1, the researcher gathered background information. This was used to formulate levels of engagement, tasks, activities, resources, learning tools and electronic tools. The result was a tutorial prototype, Tut0.

Phase 2 involved setting up the e-tutorial prototype on the LMS, ready for testing. Student volunteers were used to test the prototype through two design-development. Results from Cycle 1 were used to review, make decisions, and refine the system. The product was Tut1, which was tested in Cycle2. Similarly, Cycle2 resulted in the development of Tut2. Tut 1 and Tut 2 followed a theory first orientation to the learning process.

Phase 3 incorporated another two design-development cycles, starting with the use of Tut2 in Cycle3. Results from Cycle3 were used to evaluate, make decisions, and develop the system to form Tut3, which was used in Cycle4. Similarly, Cycle4 resulted in Tut4, the tutorial's final version. Tut 3 and tut 4 followed a problem first orientation to the learning process.

The following sections discuss a detailed account of the tutorial design and development process in each phase.

5.2 Phase 1: Conceptualisation

This section covers the initial formulating and design of the tutorial, presented as,
1) Planning and groundwork, 2) Tutorial design, 3) Tutorial construction, and 4) the operational constraints in constructing the conceptualised tasks.

5.2.1 Planning and Groundwork

This section details how information from 1) document analysis and 2) tutorial requirements analysis was used to identify the tutorial content, learning objectives and the basic requirements for the tutorial.

1) Document Analysis

The goal of this process was to identify the tutorial content. For this purpose, course handouts, examples of foundation trigonometry problems and mechanical engineering problems where basic trigonometry is needed were collected and reviewed. Table 5.1 shows a summary of the results analysed in terms of content and objectives. The content was used to generate five LMS activities based on different subtopics. The objectives were used to generate Learning activities in the form of focus questions appropriate to each subtopic. The aim and purpose of these questions were twofold: first, to stimulate students' thinking and second, to guide the review process.

Table 5.1: Learning Objectives

Content	Objectives	Focus questions
Basic trigonometry terms and concepts	Review basics, **1.** Identifying sides of a right-angled triangle in relation to a given angle **2.** Defining trigonometric ratios for angles in right-angled triangles **3.** Using trigonometric notation e.g., sin A	1. What is the meaning of the phrase “right triangle?” 2. What is the meaning of the terms opposite side, adjacent side, and hypotenuse side with respect to a right triangle? 3. How are these sides identified? 4. How do we define the concepts; trigonometric ratio, sine ratio, cosine ratio, and tangent ratio? 5. How are these concepts represented?
Pythagoras theorem	Solving problems involving the use of Pythagoras Theorem in right-angle trigonometry	1. How do you solve for the missing hypotenuse of a right triangle? 2. How do you solve for the missing leg of a right triangle? 3. How do you identify Pythagorean Triples? 4. How do you use the converse of the Pythagorean Theorem to determine if a triangle is a right triangle or not? 5. How do you determine if a triangle is acute or obtuse using the Pythagorean Inequalities theorem?
Solving right triangles	Selecting and using appropriate trigonometric ratios in right-angled triangles to find unknown sides and angles.	1. What does it mean to "solve a right triangle"? 2. Why do we need to solve right triangles? 3. How do you solve a right triangle given 2 side lengths to find the third side? 4. How do you solve a right triangle given 2 side lengths to find an angle? 5. How do you solve a right triangle given a side length and an angle measure to find a side? 6 How do you solve a right triangle given a side length and an angle measure to find an angle?
Similar triangles	Solving problems involving the use of similar triangles right angle trigonometry	1. In similar triangles, what is the relationship between corresponding angles? 2. What is a scalar factor that relates two similar triangles? 3. How to find the scale factor that relates two similar triangles?
Special triangles 45-45-90 triangle 30-60-90 triangle	Solving problems involving the use of special triangles right angle trigonometry	1. What type of triangle is the 45-45-90 triangle? 2. What is the ratio between the legs and the hypotenuse of a 45-45-90 triangle? 3. What type of triangle is the 30-60-90 triangle? 4. What is the ratio of the short leg to the long leg and the short leg to the hypotenuse in a 30-60-90 triangle? 5. How do you solve a right triangle using these triangles?

2) Tutorial Requirements Analysis

The goal of this process was to identify the basic requirements for the tutorial. For this purpose, field notes from conversations with lecturers were reviewed. The identified requirements and corresponding rationale are given in Table 5.2 below.

Table 5.2: Tutorial requirements

	Requirement	Rationale
1	Tutorial to cover the basics of foundation trigonometry	Required in mechanics calculations
2	Students to be able to go through it with minimum support from the lecturer	Timetable constraints, lectures are fully booked.
3	The system to provide content	For students to review
4	The system to provide exercises	For students to practice
5	The system to provide tutorial questions	For students to test their understanding
6	The system to automate assessment	Provide students with the results without the lectures involvement

3) Student Performance

WSU Teaching and Learning Strategy 2014-2017 foregrounded excellence, with academic success as one of the high-performance indicators, where 80% constitutes the target student success indicator for all undergraduate programs (Dwayi, 2017). Similarly, the performance objective of the e-tutorial was to achieve a success rate of 80% per activity. To achieve this target, WSU developed an academic monitoring mechanism to track and monitor students' academic progress and identify at-risk students in good time to provide effective academic intervention. Accordingly, four criteria were defined to be used to interpret and categorise students' performance:

1. At risk (weak): $X < 50\%$
2. Borderline: $50\% \leq X \leq 59\%$
3. Competent: $60\% \leq X \leq 74\%$
4. Proficient: $X \geq 75\%$

Using this performance criterion as a guide, this study chose 60% as the benchmark score showing a reasonable level of success in engaging with the content.

5.2.2 Student learning model

The tutorial design was based on the conceptualisation of the student learning process. This process aimed to map the possible steps of the student learning process as they work through the tasks explored in Section 5.2.3.

The initial theoretical/conceptual model was based on the typical procedure for tutorial programs (Gagné et al., 1981), assumptions from experience as a student and a teacher and the set-up of mathematics resources such as books and websites. The procedure starts with reviewing content in order to access relevant knowledge (theory first), which is then used to answer the tutorial questions. For example, in Dube (2010), the publisher's description of the book states that each chapter has basic theory followed by a good number of questions with their solutions. Websites like GCFLearnFree, Khan Academy and Mathtutor also have the same set-up. The procedure described above suggested the following student learning model. Students initially use the theory-first approach to construct knowledge by reviewing content and then develop proficiency through practice.

5.2.3 Conceptualisation of Tutorial design

The tutorial design involved the conceptualisation of the learning environment. This process aimed to identify essential components of the tutorial environment in response to the above requirements. An important consideration was that the tutorial environment would provide interactivity that engages students in active learning participation. This process was guided by Jonassen's (1999) description of four essential components in constructivist learning environments (see Section 2.4.4): 1) the focus of the environment, 2) related activities, 3) cognitive tools, and 4) resources. These were used as criteria for the design of the LMS-mediated tutorial.

1) Focus of the environment.

The focus of the environment was to drive the learning process and learning goal. To achieve this purpose, three different foci, based on three of the five dimensions of learning formulated by Marzano (1992), were used to design and plan the educational units (Tasks) and the respective anticipated student actions in each Task.

Task 1: Acquiring and integrating knowledge through exploring content,

Task 2: Extending and refining knowledge through practicing skills,

Task 3: Using knowledge meaningfully through application and testing of acquired knowledge.

2) Related activities

Related activities were included to deepen the students' engagement in the learning process. For this purpose, a set of LMS activities based on the content objectives identified in Table 5.1 were added to each Task. In other words, each Task included different content sections to be flashed out in an LMS activity. The aim was to get students to work with a particular mathematical idea or concept of focus in each LMS activity.

3) Cognitive Tools

Cognitive tools provided the basis for students' active participation in learning. For this purpose, Learning-activities that would help represent, organise, or automate thinking skills were considered. These Learning activities were built into each LMS activity. Two types of cognitive tools were used, learning tools and electronic tools.

Learning tools included the focus questions generated in Table 5.1 to engage students in work relating to the particular objectives. Learning tools also included tutorial questions aimed at getting the students to demonstrate their learning through answering these questions. These required different actions such as identifying sides, defining trigonometric ratios and calculating unknown sides of a given right triangle.

Electronic tools (e- tools) provided a format for Learning tools set up in the LMS. Electronic tools included online multimedia resources, online web-based tests, and LMS-based tests.

4) Resources

Resources were included to provide the desired depth of content for students to review. For this purpose, YouTube videos, Slide-share presentations and pdf notes were considered for Task 1. Interactive activities were also considered resources for Task 2 and Task 3.

Table 5.3 shows a summary of the tasks-based conceptualisation of the e-tutorial design, centred on the four essential components in constructivist learning environments (see Section 2.4.4 and section 5.2.2); (i.e., the focus of the environment, related activities, resources, and cognitive tools) as discussed above. Anticipated student actions in Task 1 were to access and review content resources, in Task 2 to practice reading questions, identify key information, formulate a solution, and solve and in Task 3 to use trigonometry knowledge and skills to solve problems. Support was provided through resources, learning tools and electronic tools.

Table 5.3: Conceptualisation of Tutorial Structure

Focus of the environment	Related activities	Cognitive tools		Resources
Tasks	LMS activities	Learning activities		
Dimensions of learning		Learning tools	e- tools	
Task 1. Explore Acquiring and integrating knowledge Task focus: Knowledge construction Expected student actions: Access and review content resources	Content sections 1. Trig basics 2. Pythagoras theorem 3. Solve triangle: sides 4. Solve triangle: angles 5. Special triangles 6. Similar triangles	Focus Questions (section 5.2.1(1))	Multimedia resources	1. YouTube video, 2. Slide-share presentation 3. pdf notes
Task 2: Practice; Extending and refining knowledge. Task focus: Proficiency development Expected student actions: Practice reading questions, identify key information, formulate a solution and solve	Content sections 1. Trig basics 2. Pythagoras theorem 3. Solve triangle: sides 4. Solve triangle: angles 5. Special triangles 6. Similar triangles	Tutorial Questions	Online test (fill blanks)	Interactive tasks
Task 3: Application and testing' Using knowledge meaningfully Task focus: Application and testing Expected student actions: Use trigonometry knowledge and skills to solve problems.	Content sections 1. Trig basics 2. Pythagoras theorem 3. Solve triangle: sides 4. Solve triangle: angles 5. Special triangles 6. Similar triangles	Tutorial Questions	LMS test (short answer)	Interactive tasks

5.2.4 Conceptualisation of Tutorial construction

Summarised in Table 5.4 are the Task items and the corresponding LMS activities, Learning activities and LMS tools used. Each task was created using the Learning module tool to provide navigation to the different LMS activities.

Table 5.4: Conceptualisation of Tutorial construction

Task	LMS Activities	Learning activities	LMS tools
Task1 Explore	Instructions	Overview of the task	LMS item page (text)
	Objectives	Summary of topics	LMS item page (text)
	1. Trigonometry basics 2. Pythagoras Theorem 3. Solving right triangle: sides 4. Solving right triangle: angles 5. Special triangles 6. Similar triangles	Focus questions on content.	LMS embedded links to online content resources
Task 2 Practice	Instructions	Overview of the task	LMS item page (text)
	1. Trigonometry basics 2. Pythagoras Theorem 3. Solving right triangle: side 4. Solving right triangle: angles 5. Special triangles 6. Similar triangles	Online practice sources	LMS embedded links to online practice sources (marked online)
Task 3 Apply/assess	Instructions	Overview of the task	LMS item page (text)
	1. Trigonometry basics 2. Pythagoras Theorem 3. Solving right triangle: side 4. Solving right triangle: angles 5. Special triangles 6. Similar triangles	Tutorial questions	LMS test using short answer question type format. (marked by a tutor)

The objective of this process was to plan how the different components of the tutorial (identified in Table 5.3) can be put together, supported by the LMS tools. The purpose of the LMS was to facilitate the learning processes through the presentation of Tasks and the corresponding instructions, educational content, and activities.

5.2.5 Operational Constraints in the construction of the conceptualised tasks

The conceptualisation process revealed several inconsistencies between the original conceptions and design of the LMS and Learning activities of the tutorial and the actual form being developed for implementation. The inconsistencies and the approaches taken to overcome these are presented using the following themes.

1) Split in design, knowledge package vs proficiency development,

2) Disparity of actions; recognition vs production,

3) Use of open response questions; feasibility for ICT using LMS as a tool,

4) e-Learning tools; perceived ease of use vs students' ICT literacy skills,

5) Declarative vs Procedural knowledge.

1) Split in design, knowledge construction vs proficiency

It was planned that students would first acquire and integrate knowledge through reviewing content, then extend and refine their understanding through practice. In other words, students first review content and construct knowledge, followed by proficiency development (refer to

Table 5.3). However, practicing fluently and efficiently (proficiency) indicates a need to support students as they work by providing access to resources. This was resolved by inserting resources within the tutorial questions using the LMS test tool.

2) Disparity of actions; recognition vs production

During the tutorial design, the possibility of a student having strategy knowledge available but failing to use it (production deficiency) was anticipated. Therefore, in each activity, tutor-generated prompts or strategy activators were incorporated. Prompts are economical in that they activate learners' prior knowledge and processes by presenting minimal pieces of information. According to the cognitive load perspective, presenting prompts during learning instead of before positively affects learning outcomes. Providing scaffolding on a "needs basis" (e.g., pop-ups) is difficult to implement in a LMS because it requires HTML programming. Instead, prompts were given (as answers to choose from) on a question-by-question basis. However, this brought a conflict between recognition and production. This was resolved by randomly presenting the given answers in the form of a Toolbox (see Appendix 1.4a) in order to make students think before they choose.

3) Use of open response questions; feasibility for ICT using LMS as a tool,

Learning to do mathematics requires students to do open response tasks, which present contexts in which mathematics can be used. Open response refers to a question or problem requiring students to show steps to obtain the answer (see Appendix 1.4b). Open response tasks can be answered using the math editor tool in the LMS. However, students need some time to learn how to use it. This might slow them down. Secondly, open response tasks cannot be automatically marked by the LMS; they need to be marked by the tutor. So, immediate feedback, which is one of the advantages of LMS-based e-learning, is likely to be lost. As a result, fill-in-multiple blanks were included to simulate LMS correctable open-response tasks (see Appendix 1.4a).

4) e-Learning tools; perceived ease of use vs students' ICT literacy skills

From Figure 5.2: Learning Process Model , several e-learning tools were planned to support students learning. For example, Math editor, Calculator, Google docs, Concept map, Info-graphic, etc. These are supplementary to the LMS interface. Therefore, the students had to learn how to effectively use these e-learning tools so as to carry out the task at hand. Moreover, it was noted that perceived usefulness, perceived ease of use, computer self-efficacy and the students' ability to work independently significantly affected their performance in online tutorials. This indicated a need to address (e.g., by training) these issues first before the students started the tutorial. However, such an intervention may have disrupted the planned mathematical engagement, as the student's focus may be on how to use the tool. Therefore, a procedure sheet was constructed to guide the students as they worked (see Appendix 11).

5) Declarative vs Procedural knowledge

It was noted from literature that instructional support of learning is effective if it ensures that the student knows what to do in a certain learning situation (declarative knowledge), when and why to do it (conditional knowledge), as well as how to do it (procedural knowledge). This can be achieved through strategy training that instructs students about what strategy to use, when and why to use it, and how to use it. However, despite its effectiveness, strategy training is very time-consuming. This training would therefore be difficult to incorporate within the LMS-mediated tutorial. Hence, contrary to the constructivist principle that learning is an active process of constructing rather than acquiring knowledge, a face-to-face direct instruction component was planned.

5.3 Phase 2: Iterative design-develop; Cycles 1 and 2

The evaluation e-tutorial conceptualisation in Phase1 indicated several limitations in the e-tutorial design. Cycle 1 of the iterative design-develop Phase2 involved making minor changes to the e-tutorial to correct these limitations. However, the results of Cycle 1 (see section 6.1.7) indicated several challenges in the e-tutorial use. Therefore, Cycle 2 involved making further changes to the e-tutorial to correct these limitations. This section details the revised design assumptions, learning process model and the changes in the design and construction of the e-tutorial in Phase2.

5.3.1 Initial Design Assumptions

The student learning model (section 5.2.2) was translated into the following design assumptions. Students would: 1) review content first in order to access relevant knowledge. 2) use the acquired knowledge to answer the tutorial questions (Solve problems to test understanding). This is represented by the learning process model in Figure 5.2

Learning Process Model

Read content (pdf, YouTube videos, Slide share presentation)

⇩

Practice, do tutorial questions,

⇩

Review feedback: mark correct/incorrect answers.
Student Activity decision: Mark > 60% go to next activity or Mark < 60% redo activity.

Figure 5.2: Learning Process Model

5.3.2 Tutorial Design

In Cycle 1, the tutorial design involved organising the learning environment in terms of the essential components of the tutorial environment (see section 5.2.3) in response to the above design assumptions and process model. In Cycle2, changes were made based on results from Cycle 1. The tutorial design was driven by the three Tasks (see section 5.2.2), where every task included each of the different content objectives (see Table 5.2). Table 5.5 shows a summary of Phase2 e-tutorial design. Changes made in Cycle2 are highlighted in ***bold italics.***

Table 5.5: Tutorial Design

Focus of the environment	Related activities	Cognitive tools		Resources
Tasks	LMS activities	Learning activities		
Dimensions of learning		Learning tools	e- tools	
Introduction *Acquiring and integrating knowledge*	Present overview of the tutorial	A text-based overview of the tutorial		***An interactive flash video presentation***
Objectives *Acquiring and integrating knowledge*	Present an overview of the contents of the Topic	A text-based overview of the contents of the Topic		***A pre-test was added as an LMS test.***
Task 1. Explore *Acquiring and integrating knowledge* Task focus: Knowledge construction Expected student actions: Access and review content resources	Content sections 1. Trig basics 2. Pythagoras theorem 3. Solve triangle: sides 4. Solve triangle: angles 5. Special triangles 6. Similar triangles	Focus Questions ***Add Quizlet to each content section.*** ***make feedback per Quizlet question, elaborate***	Multimedia resources ***embed in LMS.***	Multimedia resources: YouTube video, Slide-share presentation pdf notes ***short, topic-focused video***
Task 2: Practice; *Extending and refining knowledge.* Task focus: Proficiency development Expected student actions: Practice reading questions, identifying key info, planning a solution and solve	Content sections 1. Trig basics 2. Pythagoras theorem 3. Solve triangle: sides 4. Solve triangle: angles 5. Special triangles 6. Similar triangles	Tutorial Questions	Online test (fill blanks)	
Task 3: Application and testing *Using knowledge meaningfully* Task focus: Application and testing Expected student actions: Use trigonometry knowledge and skills to solve problems.	Content sections 1. Trig basics 2. Pythagoras theorem 3. Solve triangle: sides 4. Solve triangle: angles 5. Special triangles 6. Similar triangles	Tutorial Questions	LMS test short answer format, marked by the tutor. ***Fill-multiple-blanks Minimum of 3 sections*** ***Add hints on answer format***.	

Task 1-Explore had three items, introduction, objectives and LMS activities.
1) Introduction presented a text-based overview of the tutorial (Cycle 1). In Cycle 2 this was changed to an interactive flash video presentation (see section 6.3.1.1)
2) Objectives presented a text-based overview of the contents of the Topic. In Cycle 2, a pre-test was added to the objectives item (see section 6.3.1.1)
3) LMS activities (content sections) to get students to work with a particular mathematical idea or concept in each activity. Each activity had two parts, a) resources and b) Learning activity (tutorial questions). Resources were in the form of YouTube videos, SlideShare presentations and pdf notes. In Cycle 1, Learning activities were in the form of focus questions to assist students in reviewing the content. No answers were required. In Cycle 2, Quizlets were added to the Learning activities (see section 6.1.7). These were in the form of fill blanks, short-answer questions (marked by the system).
Task 2-Practice had three items in the form of online practice links. Learning activities included fill blanks, short-answer, tutorial questions (marked online).
Task 3- Apply/assess. In Cycle 1, this item had six questions (on each of the different content objectives) in short answer format, marked by the tutor. In Cycle 2, this was changed to Fill-multiple-blanks format (marked by the system), with a minimum of 3 sections per question (see section 6.1.7).

5.3.3 Tutorial construction

The tutorial system was hosted in a LMS that provided an electronic environment to present information, introduction, content and to capture and store students' responses and results. It was part of the Mathematics I course created in the LMS. As conceptualised (see section 5.2.3), it was accessible through a menu item named Trigonometry, which contained the three tasks, and each was subdivided into content sections. Each task was created using the Learning module tool, which provided the navigation to the different content (see Table 5.4).

5.3.4 Design limitations and approaches taken to overcome them.

The results of this iterative design-develop Phase2 indicated several challenges and shortcomings in the design. The design limitations and the approaches taken to overcome them are presented using the following design features discussed in section 5.2.2:
1) focus of the environment,
2) related activities,
3) resources
4) cognitive tools.

1. Focus of the environment.

The focus of the environment was to drive the learning process through three different tasks; Task 1: acquiring and integrating knowledge through exploring content, Task 2: extending and refining knowledge through practicing skills, and Task 3: using knowledge meaningfully through application and testing of acquired knowledge. However, results suggested that using the module tool for each task introduced unnecessary extra navigation. This was resolved by changing the focus of the environment from Tasks (see Table 5.3 in section 5.2.2) to LMS activities (see Table 5.6 in section 5.3.4). These LMS activities were extracted from Task 1 and Task 3 in Tut1 and Tut2.

2) Related activities

Related activities (LMS activities) were included to get students to work with a particular mathematical idea or concept in each activity. The initial design assumptions and learning process model (see section 5.2.1) assumed that this objective would be achieved when students first review content to access relevant knowledge and then use the acquired knowledge to answer the tutorial questions. However, results indicated that students preferred to do/try tutorial problems first but explored the content when doing tutorial questions. This suggested that the initial design assumptions and learning process model did not adequately represent the learning process. This limitation was resolved by introducing Quizlets (in each LMS activity of Tut2) as rehearsal problems to challenge students to review resources when they get stuck. This resulted in a reduction of dimensions of learning from three (section 5.2.2(1) to two:

a) Developing/refining knowledge through adaptive rehearsing and exploring of content (formed by combining dimensions of learning from Task 1 and Task 2 (see section 5.2.2)).

b) Using knowledge meaningfully through application and testing of acquired knowledge (from Task 3 (see section 5.2.2)).

3) Resources

Resources were included to provide the desired depth of content for students to review. This included YouTube videos, Slide-share presentations and pdf notes for Task 1 and interactive internet Learning activities for Task 2. and Task 3. However, student experiences indicated the internet resources were unreliable (see section 6.2.3) and required too much reading. This was resolved by introducing precision content resources in the form of short, topic-focused flash video clips. These were embedded in the test tool's instructions section to give students easy access to content when doing Quizlets.

4) Cognitive Tools

The cognitive tools provided the basis for students' active participation in learning. These included learning tools (in the form of focus questions), generated in Table 5.1, and tutorial questions based on the subtopics (content sections). The electronic tools, in the form of online tests, provided a structure for learning tools set up in the LMS. Two answer formats were used in the tasks, the fill-multiple-blanks and the short answer for open response tasks (see Appendix 1.4). By LMS design, short open answer questions required the tutor to mark (see Appendix 6.1a). Marking was done after each tutorial session. So, immediate feedback, which is one of the advantages of LMS-based e-learning, was lost. As a result, all tutorial questions were set as fill-in-multiple blanks to simulate LMS correctable open-response task that can provide immediate feedback.

Table 5.6 shows a summary of the resultant Activity structure for each content area, based on two dimensions of learning.

Table 5.6: Re-conceptualisation Activity Structure

Focus of environment	Related activities	Cognitive tools		Resources
LMS activities	Dimensions learning	Learning tools	e-tools	
Content sections: 1. Trigonometry basics 2. Pythagoras Theorem	Each Content section based on two dimensions of learning.			Topic-focused flash videos, and pdf notes embedded in LMS.
3. Solving right triangle: side 4. Solving right triangle: angles	1. Developing/refining knowledge through adaptive rehearsing and exploring of content	Rehearse questions Fill in blanks questions.	Interactive quiz	Quizlet embedded in LMS
5. Sine rule	2. Using knowledge meaningfully through application and testing of acquired knowledge	Tutorial questions Fill in multiple blanks questions.	LMS test	

5.4 Phase 3: Iterative redesign-develop; Cycles 3 and 4

The evaluation of the e-tutorial at the end of iterative design-develop Phase2 indicated several limitations in the e-tutorial design. Cycle 3 of the iterative design-develop Phase3 involved making significant changes to the e-tutorial to correct these limitations. Similarly, the Cycle 3 results indicated several challenges in the e-tutorial use. Therefore, Cycle 4 involved making further changes to the e-tutorial to correct these limitations. This section details the revised design assumptions, learning process model and the changes in the design and construction of the e-tutorial in Phase3.

5.4.1 Revised Design Assumptions

Summary of key results from design-develop Phase 2 (see section 6.3.10) suggested the following student learning model: Students prefer to do or try problems first and review content to get answers to experienced challenges. Therefore, the approach was changed from theory-first to problem-first by making a challenge (introduced as Quizlets) the core of the learning process. This translated into the following design assumptions. Students would:

1) review and work out Quizlets problems using pen and paper (rough work).

2) use solutions from rough work to complete the online activity.

3) explore resources when they experience challenges answering Quizlet questions as directed by immediate feedback per Quizlet question to the relevant section(s) in resources.

4) review content and try Quizlet or test again.

5) achieve a pass mark of 60% as a result of the above actions.

These assumptions were used to develop the learning process model illustrated in Figure 5.3.

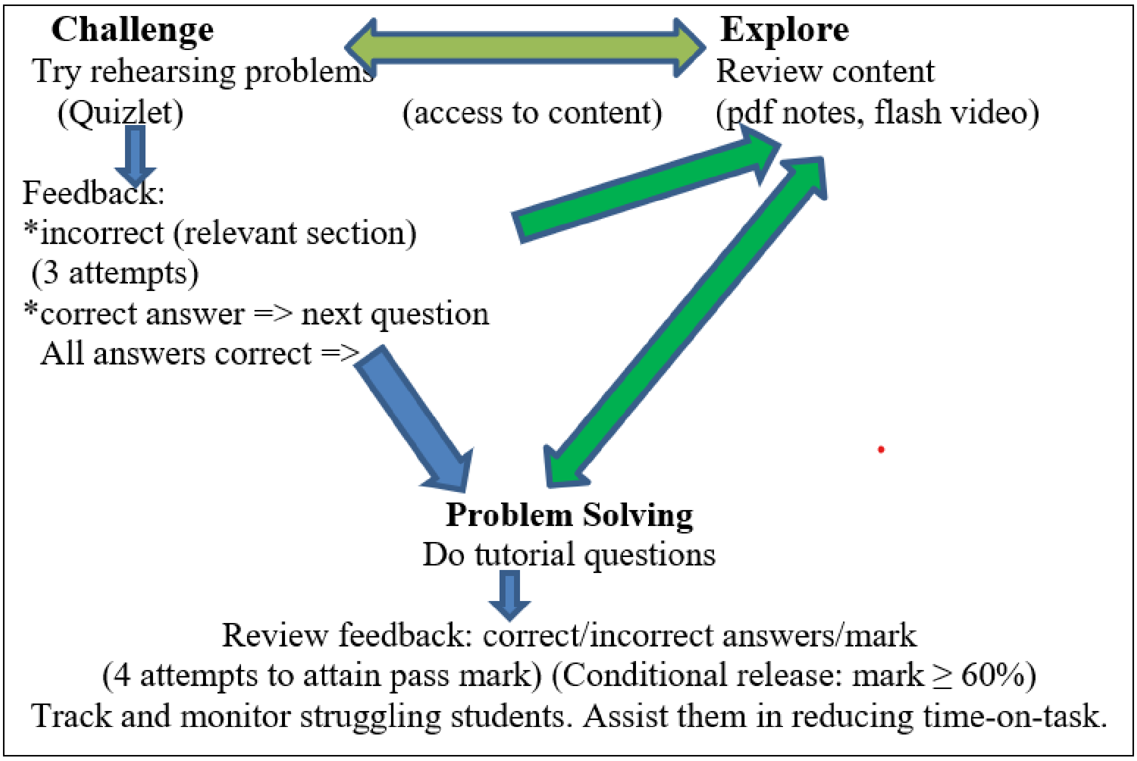


Figure 5.3 Learning Process Model

5.4.2 Tutorial Design

The above assumptions required a number of significant design changes. Table 5.7 shows a summary of these Phase3 e-tutorial re-design. Minor changes made in Cycle3 and Cycle 4 are highlighted in ***bold italics.***

Table 5.7: Tutorial re-design

The focus of the environment	Related activities	Cognitive tools		Resources
LMS Activities	Dimensions of learning	Learning activities		
		Learning tool	Electronic tool	
Orientation sections: Information	Each Orientation activity based on: Acquiring/integrating knowledge	Overview of the tutorial Add a short conditional release test.	An interactive presentation LMS test	Flash video presentation
Introduction		Overview of the content objectives Pre-test	LMS test	LMS test
Content sections: 1. Trigonometry basics 2. Pythagoras Theorem 3. Solving right triangle: side 4. Solving right triangle: angles 5. Sine rule 6. Cosine rule	Each Content section activity based on: 1. Developing refining knowledge through adaptive rehearsing and exploring of content	Fill-blanks questions	Quizlet test 3 attempts maximum	Topic-focused flash videos, and pdf notes embedded in LMS
	2. Using knowledge meaningfully through application and testing of acquired knowledge	Fill-multiple-blanks questions Minimum of 3 sections Hints on answer format	LMS test conditional release 3 attempts	

1) Change the focus of the environment from Tasks (see Table 5.3 in section 5.2.2) to LMS activities (see Table 5.1 in section 5.2.2). The tutorial design was driven by LMS activities formed by combining Tasks 1 and 2 in the previous design. This resulted in two LMS activities sections, Orientation and Content. The Orientation section LMS activity had two related activities; Information (to provide an overview of the tutorial) and Introduction (to give an overview of the content objectives).

2) Each Content section LMS activity had two related activities based on two dimensions of learning (see section 5.3.4(2) or anticipated student actions (see section 5.2.2(1):

a) developing and refining knowledge through adaptive rehearsing and exploring of content

b) using knowledge meaningfully through application and testing of acquired knowledge

3) The LMS activities in the Content sections had three parts Quizlet and resources followed by tutorial questions, see Appendix 1.4.

4) Resources were in the form of short, topic-focused, flash videos (small) and pdf notes (big), accessible at all times (whether doing Quizlet or tutorial questions).

5) All questions were fill-multiple-blanks to replicate steps taken in working out a problem.

5.4.3 Tutorial Construction

In Cycle3 and Cycle4, the e-tutorial was accessible through a menu item named Trigonometry, which contained the LMS activities (Orientation and Content sections). It was created using the Learning module tool, which provided the navigation structure (see Appendix 1.3(d). Summarised in Table 5.8 are the LMS activities items and the corresponding LMS tools used in the construction.

Table 5.8: Tutorial construction

LMS Activities	Learning activities	LMS tools
Orientation sections:		
Information	Overview of the tutorial	LMS item page (text)
Introduction	Overview of the content objectives Pre-test and KW questionnaire	LMS test LMS test Google form embedded
Content sections: Activity1. Trigonometry basics Activity 2. Pythagoras Theorem Activity 3. Solving right triangle: sides Activity 4. Solving right triangle: angles Activity 5. *Sine rule* ***Activity 6. Cosine rule***	Quizlet, Resources Tutorial questions	LMS test. Quizlet created using Quiz Creator, deployed as flash video embedded in the instructions section of the Test tool. Resources (flash videos, and pdf notes) embedded in the instructions section of the test tool. Tutorial questions using fill-multiple-blanks questions format. (marked by the system)

5.4.4 Design limitations and approaches taken to overcome them.

In Cycle3, several limitations and shortcomings in the e-tutorial design were encountered. To correct these limitations and weaknesses, Cycle4 involved making minor changes in design assumptions and to the e-tutorial (i.e., introduction, Quizlets feedback and tutorial questions) described below.

1) Design assumptions

The initial tutorial design assumed that the activities would be done only once. In Cycle3, it was observed that struggling students needed to be allowed to review content and try the Quizlets or tests again in order to improve. Therefore, in Cycle4, progress from one activity to another needed to be locked until the student achieved the benchmark score of 60% (see section 5.2.1(3)). This was achieved through the adaptive/conditional release function of the LMS.

2) Introduction

Include a short quiz to motivate students to read the introduction and test comprehension. This was achieved through a conditional release LMS test.

3) Quizlets and test attempts

It was observed in Cycle3 that students' performance was still poor. This suggested that these students needed some assistance. This was achieved by making feedback more elaborate, directing students to relevant sections in resources, and allowing multiple attempts to enable students to review resources and try again. However, some students attempted the Activity1 test up to four times before getting it right. The number of attempts needed to be controlled in order to enhance progress. Therefore, in Cycle4, students were given only three attempts or chances to try the same question again, after which feedback was set up to tell the student to ask a tutor for assistance.

4) Tutorial questions

In Cycle3, the attempts statistic table indicated tutorial questions errors, which resulted in 0% pass rates in activity steps/sections. In Activity 2, two were identified; in Activity 3, one was identified; in Activity 4, one was identified; in Activity 5, three were identified. The system allowed correcting the answer and remarking. This was achieved through the editing of tutorial questions.

5.5 Summary

Table 5.9 presents a summary of the main features of the final tutorial model based on the changes made in response to activity design and system design issues identified in Cycles 1, 2, 3 and 4. The table shows how the LMS was used to seamlessly facilitate learning administration (i.e., content delivery, assessment delivery, and communication of results) by using the test tool to generate the e-tutorial structure and activities.

Table 5.9: Primary features of the e-Tutorial Model

	Item			ICT tool
1	Information on how to access the activities			Static text
2	Introduction: present an overview of the tutorial			
	1. Interactive presentation			Flash video
	2. Short quiz to test reading and comprehension			Conditional release LMS test
3	Objectives: present an overview of the trigonometry topics			
	1. Pre-test			LMS test
	2. KWL questionnaire to identify the knowledge gap			Google form
4	Content sections		each made up of three parts:	
	Activity 1. 2. 3. 4. 5. 6.	Content Trigonometry basics Pythagoras Theorem Solving right triangle: sides Solving right triangle: angles Sine rule Cosine rule	1. Quizlet, questions in the form of fill blanks with immediate feedback	Quiz software
			2. Resources: accessible at all times (whether doing Quizet or Tutorial questions) • short, topic-focused video • long notes,	Flash video pdf
			3. Tutorial questions: test questions in the form of fill-multiple-blanks, with a minimum of three spaces	Conditional release LMS test

The final e-tutorial was achieved through progression from cycle to cycle which involved the following significant changes:

1. Cycle 1: Model theory oriented. Resources were seen as the core of the learning process.
2. From Cycle 1 to Cycle 2: Quizlets were introduced as a *motivating* element.
3. From Cycle2 to Cycle3: A learning model change from theory oriented to problem-oriented with adaptive rehearsing and exploring of content. Quizlets became the core of the learning process.
4. From Cycle 3 to Cycle 4: Conditional release was introduced as a *regulating* element.

6 PHASE 2 RESULTS

6.1 Introduction

This chapter outlines and discusses the results relating to how students engaged with the e-tutorial activities. It presents the results of the in-class observations, interviews, questionnaires, screen capture videos, and system-generated data. For each modality, the data collection process is briefly described, followed by a transcription of raw data of the results, presented as a data display matrix. This is followed by a brief discussion of individual elements (that emerged from the data) that gave specific insights into student engagement.

6.2 Cycle 1 Results

In Cycle 1, a group of student volunteers from the first-year mechanical engineering class tested the e-tutorial.

6.2.1 Student Profile

The results from the student profile questionnaire (see Appendix 12.2), completed by thirty-seven students (out of 43 in the class), indicated an almost equal number of male (51.4%) and female (48.6%) students.

Most of these students (64.9%) were between 17 and 20 years old. Of the rest, 21.6% were between 21 and 23, 8.1% were between 24 and 26 and 2.7% were more than 26 years old.

Among the respondents, a significant number had completed their matric the previous year (51.4%), while others had varying amounts of gap years: one (16.2%), two (16.2%), or more than two (16.2%). Additionally, their self-rated computer experience ranged from Intermediate (61.1%) to Novice/Beginner (30.6%) and Expert (8.3%).

In Cycle 1, eleven students (three male and eight female) of the 43 (25%) responded to the call to test the system. The students were asked to do a series of tasks using the e-tutorial during the Mathematics tutorial period. They were given no training but had access to other resources that they would have in the regular classroom environment (e.g., a scientific calculator). Also, the researcher was available to answer any questions the students may have had.

6.2.2 Know-Want to Learn (KWL) questionnaire.

The purpose of this item was to enable students to evaluate self-knowledge about the topic by filling in the KWL survey. In the objectives item, students were asked to assess what they knew or wanted to learn about the topic by filling in the K-W form (questionnaire). Results from the this questionnaire are presented in Table 6.1.

Table 6.1: Results from the Know-Want to learn questionnaire.

Objective	Student responses		
	Know	Want to learn	Total
1. Identifying sides of a right-angled triangle with-respect-to a given angle.	7	4	11
2. Defining trigonometric ratios for angles in right-angled triangles	5	6	11
3. Using trigonometric notation e.g., sin A	5	6	11
4. Using a calculator to find approximations of the trigonometric ratios of a given angle measured in degrees	8	3	11
5. Using a calculator to find an angle correct to the nearest degree, given one of the trigonometric ratios of the angle	7	4	11
6. Selecting and using appropriate trigonometric ratios in right-angled triangles to find unknown sides	5	6	11
7. Selecting and using appropriate trigonometric ratios in right-angled triangles to find unknown angles correct to the nearest degree	6	5	11
8. Solving problems involving the use of right-angle trigonometry	6	5	11
Total (average)	49 (6)	39 (4.5)	

Table 6.1 indicates that all 11 student volunteers completed this self-evaluation. Of their responses, it can be noted that there was an even split (given that the number of responses was odd) for five objectives: 2, 3, 6, 7 and 8, while more students judged that they knew the remaining three objectives: 1, 4 and 5. Overall, there was a higher number of *know* (K) than *want to learn* (W) responses. This suggests that students thought they knew more than they needed to learn. However, a more detailed analysis of responses indicated that their self-knowledge judgements may have been inaccurate. For example, students need to know objectives 1 and 2 (**Defining trigonometric ratios** for angles in right-angled triangles) to achieve objective **6** (Selecting and **using appropriate trigonometric ratios** in right-angled triangles **to find unknown sides)**. However, some students (e.g., 2, 3, 10) indicated W (Want to learn) for objectives 1 or 2 and K (Know) for objective 6. Results suggested that many of the students had inappropriate self-knowledge. Many of the respondents didn't know, but they thought they knew.

6.2.3 In-class Observation

The Observation focused on how students engaged with the e-tutorial activities and the challenges they encountered. The researcher recorded observation notes based on his encounters with students who asked for assistance when they experienced difficulties. Results are summarised in Table 6.2.

Table 6.2: Cycle 1 Observation data

Focus area	Observation
1. Student Engagement	1.1 All students (11) started with the tutorial questions by doing rough work. 1.2 Students write down on paper and then copy it to the computer. 1.3 No evidence of interaction with multimedia resources.
2. Challenges	2.1 S1: abbreviations, e.g., sin, used by the student were not catered for in the system. 2.2 S2: student got the wrong answer. (student comments, "did not use notes, used knowledge (*why*) I thought I know this". 2.3 S5: the faced problem of correcting mistakes on the computer 2.4 S6: Fill-in-blanks puzzling: e.g., Task 1, Activity 3 [ ] = [ ] / [ ] (student comment, "at least give one of the three") 2.5 S11: The system answer seems to be wrong. The student was frustrated after getting it wrong three times. (student's comment, "the computer makes me stupid").

In-class observations provided insight into the following four categories of engagement: 1) student actions, 2) system use, 3) set-system-answers, and 4) students' experience.

1) Student actions

In-class observations suggested that no student reviewed the Introduction and no student reviewed multimedia resources (1.3; 2.2). Results further indicate that all students started by doing rough work on the tutorial questions (1.1), writing the solutions down on paper then copying them to the computer (1.2). The student actions suggested that these students were more interested in engaging with the mathematical tasks than reviewing the introduction or multimedia resources.

2) System use

The students faced several challenges while using the system, e.g., filling the blanks, correcting mistakes (2.3), and constantly being marked wrong by the system (2.4; 2.5). Student work samples (section 6.2.7.1) indicate that their answers were incorrect due to errors such as spelling, or they used the wrong format for the correct answer. The results suggested that these students needed some training on using the system, especially the introduction and how to do the activities.

3) Set-system-answers

In addition to the challenges, some shortcomings in the set-system-answers (the answer the system checks responses against) were observed. For example, abbreviations were not catered for, fill-in-blanks were puzzling, and some were wrong (2.1; 2.4; 2.5). Results suggest corrections had to be made in the set-system-answers to rectify these flaws.

4) Students' experience

Some students experienced frustration after entering an incorrect response three times (2.5). This may be linked to an inappropriate belief that they knew the topic. Hence, they "did not use notes, used knowledge" (2.2). The results suggested that these students needed to be identified and supported by the tutor.

6.2.4 Screen-capture Data

At the beginning of the session, students were shown how to activate the screen recording software employed to capture on-screen activity in a digital video format. In line with the ethical considerations (see section 4.5.3), students were in control of screen capture software and were encouraged (but not forced) to switch it on. In Cycle 1, only two students used the screen capture software. Results are summarised in Table 6.3.

Table 6.3: Observations from screen-capture video

Focus area	Observation
1. Student Engagement	Student1 1.1 Do KWL questionnaire (12.51 - 16.20) 1.2 Accessed Activity1 after 19.44 minutes and scrolled down to tutorial question 51seconds later, at 20.35. 1.3 Open Activity 4 at 38.32, 38.41 scroll down to tutorial questions. 1.4 No multimedia resource was opened. Student2 1.5 Open Objectives at 7.20 - 7.42 1.6 Open KWL at 7.43 - 11.11 1.7 Open Introduction at 11 28 - 11.30 1.8 Moved to desktop at 11.30 – 12.03 1.9 Open Activities 12.03; read instructions 13.03; choose Activity 4; focus questions 14.00; Play YouTube video 15.40; start questions 18.20; open computer calculator 30.30; (did questions 1, 2, 3) 1.10 Save and submit 33.52. 1.11. Student2 keep on looking sideways, probably checking on how another student is doing it
2. Challenges	Student1 2.1 Copy and paste from Toolbox not smooth; student resorted to typing in the answers. (worked well, researcher observation), 2.2 Student1 did not submit the answers

Screen-capture video data suggest two types of engagement: 1) student actions and 2) system use.

1) Student actions

Screen-capture video data indicated that both students completed the KWL questions taking about three minutes (1.1; 1.6). When Student1 opened the activities, he went straight into answering the tutorial questions (1.2). This student did not review the resources, despite the resources being visible on the screen. Student2 played the YouTube video for 3.40 minutes before starting the tutorial questions (1.9). This student also briefly (2 seconds) looked at the Introduction (1.7). The results suggest that both students spent more time doing tutorial questions than the Introduction.

2) System use

Copy and paste from Toolbox was not smooth; typing answers worked well (2.1).

6.2.5 Interview Responses

In Cycle 1, one session of interviews was conducted. Five (5) students agreed to be interviewed. Interviews were recorded and later transcribed, as shown in Appendix 4.1. These interviews were semi-structured, comprising predetermined questions on the student's teaching and learning needs, challenges, perceptions, attitudes and experiences in the teaching and learning situation. The Results are summarised in Table 6.4.

Table 6.4: Summary of Interview responses.

Focus area	Student responses
1. Student Engagement	1.1 S3: "I find the tutorials from the software very exciting," 1.2 S4: "I find this kind of tutorial very easy. 1.3 S4: you can also learn more about how to use the computer." 1.4 ALL: "Yes, we can do it on our own because you showed us how to log in to the software and how to work using e-tools. We know how to find the tools." 1.5 S3: "You can sit at home on your own and do these tutorials in your spare time." 1.6 S1: "...our lecturers provide us with tutorial classes with tutors to assist us."
2. Challenges	2.1 S5: "For a person who is computer illiterate, they will probably find it difficult because it is based on working on the computer." 2.2 S2: "When using this software, you must be computer literate. You need to have computer skills and know computer basics

Interview responses provided insight into the following two categories of engagement: 1) student experience and 2) system use.

1) Student experience

Interview responses indicate that idea of tutorials was not new to them (1.6). Students found working on the computer "exciting" (1.1), easy (1.2; 1.4; 1.5) and also helpful in improving their computer skills (1.3). The results suggest that the students found the e-tutorial exciting and easy to work with.

2) System use

Interview responses suggest that although some students found working on the system easy (1.2; 1.4; 1.5), novice computer users may need support from the tutor on how to use the system "because it is based on working on the computer" (2.1; 2.2). The results suggested that lack of computer literacy could be a barrier affecting how students completed the tutorial.

6.2.6 Journal Responses

All students were encouraged (not forced) to complete a learning journal (Section 4.2.1) detailing their experiences during the tutorial. Ten out of the 11 students submitted their journal responses. Results are summarised in Table 6.5

Table 6.5: Summary of Journal responses

Focus area	Student responses
1. Student Engagement	1.1 Total of responses was 10 1.2 Task was informative 79%, exciting 86%, interesting 86% 1.3 e-tools made the task easy 72 %, quick 72% 1.4 While doing the task, felt confident 72%, satisfaction 64% 1.5 Students asked for help from a tutor 78%, peers 71 %
2. Challenges	(What did you find challenging when you were doing the task?) (open-ended question). 2.1 "CALCULATOR, it is hard to do tasks without a calculator." 2.2 (*how to*) "Launch maths editor." 2.3 "I found that using e-tools is not easy as I thought." 2.4 "I need to know more about using trigonometric ratios and using a calculator to get correct answers". 2.5 "finding the missing angle." 2.6 "I couldn't get all equations example sine rule."

Journal responses suggest three types of engagement: 1) student feeling, 2) system use, and 3) system shortcomings.

1) Student experience

Journal responses indicate that, on average, 70% to 80 % of students found the e-tutorial informative, easy, and quick to use, and they felt confident and satisfied (1.2; 1.3; 1.4). When they had problems, students stated that they asked for help from their tutor or peers (1.5). The results suggest that the students found the e-tutorial interesting to work with.

2) System use

Students experienced some challenges with using the computer (2,1; 2.2; 2.3) and with basic trigonometry skills (see 2.4; 2.5) 3). The results suggest that some students needed more time to learn how to use the computer, for example, the equation editor tool used to answer short open-answer questions. The results suggest that these students needed some training on using the system.

3) System shortcomings

One student's comment (2.6) suggests that content on Sine Rule should be added. The results indicate that content needed to be reviewed.

6.2.7 LMS Generated Data.

As the students worked on the e-tutorial, formative assessment data was automatically generated by the LMS and displayed in the grade centre. The grade centre resembles a spreadsheet designed to be used as a grade book. Each row represents a user (student) in the course, and each column includes information for assessment items such as tests. In Cycle 1, only four types of data were extracted from the grade centre of the LMS due to the small number of students involved in the testing (section 6.2.1); 1) Students' work samples, 2) Item analysis, 3) Attempts statistics and 4) System responses.

6.2.7.1 Student work samples

Student responses (answers) in the activities were accessed via the grade attempt function of the grade centre. From this, several issues relating to shortcomings in the system for entering or marking answers were identified (see Appendix 6.1c). These are summarised in Table 6.6 below.

Table 6.6: Issues relating to set-system-answers.

Issue description	No. of cases	Observations
Activity 1		
Question1: Name sides of a right triangle		
1. Student used the correct format (as indicated in the Toolbox) and got one right answer. The system allocated 0 mark.	7 (out of 14 attempts)	O1: No provision for partial credit was made
2. Student used the wrong format, i.e., symbol instead of the full word.	2 (out of 14 attempts)	O2: Acceptable format indicated in Toolbox is not clear
3. No answer given	2 (out of 14 attempts)	O3: no attempt
Question2: Define the trig ratios with-respect-to a given angle		
4. Correct answer marked wrong by LMS due to spelling error.	3(out of 14 attempts)	O4: No provision for typing errors
Activity 2		
5. No attempts	0 (out of 6 attempts)	O5:student attempted this activity. Why?
Activity 3		
Question 2:Relationship between corresponding side and angles of similar triangles		
6. Challenge in completing questions.	6 (out of 6 attempts)	O6: answer format too constraining
Activity 4		
Question1: Write a mathematical representation. Pythagoras theorem		
7. Correct answer marked wrong by LMS	7 (out of 13 attempts)	O7: No provision for alternative answers
Question2: Calculate the value of the missing side		

8. Pythagoras theorem correct, but square root not taken	8 (out of 13 attempts)	O8: The student's answer is not in a simplified form; the system answer is in simplified form (answer format) This could be a conceptual/mathematical error, or a technical error (not knowing how to indicate the square root)
Question3: In Figure 16, AB = c, BC = a and AC = b. Write an expression for quickest way of calculating the hypotenuse side b		
9. Challenge to write x^2 in the required format, i.e... x^2	7	O9: Required format is too constraining
Activity 5		
10. Correct answer marked wrong by LMS.	6 (out of 8 attempts)	O10: Steps in student answer do not correspond with set-system-answers

Table 6.6 provided insight into the following two categories of engagement: 1) set-system answers and 2) student errors.

1) Set-system-answers

Student work samples suggest the following types of issues relating to shortcomings in the set-system-answers: 1) No provision was made for partial credit (O1), typing errors (typos), (O4), or alternative answers (O7), 2) acceptable format indicated in Toolbox was not clear, (O2), 3) answer format too constraining (O6; O9), and 4) steps in student answer did not correspond with set-system-answers (O10). Results suggested a need to make provision, in the system answer formats, for partial credit, typing errors and alternative answers, steps in student answer to correspond with set-system-answers and look for alternate answer formats in Questions which answering was too constraining.

2) Student errors

Even with the system's weakness in judging correct responses, it was still quite common for students to repeatedly submit incorrect answers due to spelling or typing errors (O4) or using the wrong format for the correct answer (O2). However, not simplifying the answer (O8) could have been a conceptual/mathematical error or a technical error (not knowing how to indicate the square root). The results suggested that these students needed to be cautioned about these errors.

6.2.7.2 Item analysis

The LMS-generated item analysis provided statistics on the overall performance in each activity and individual test questions. The aim was to assess the quality of those items and the test as a whole and use this information to improve questions. Table 6.7 shows a summary of Cycle 1 item analysis.

Table 6.7: Summary of Cycle 1 Item Analysis

Activity	Attempts status		Average performance		Questions	
	Completed	In Progress	Time	Score	Discrimination	Difficulty
Task1-Activity1	14	5	01hr40min	45%	3 good	3 medium
Task1-Activity2	No data	No data	No data	No data	No data	No data
Task1-Activity3	6	3	00hr0min	25%	Cannot calculate	1 hard
Task1-Activity4	13	2	00hr20min	0.7 %	2 good 1 not	3 hard
Task1-Activity5	8	0	00hr1min	21%	1 good	1 hard
Task 2	30	2	00hr20min	46%	5 good	1 easy 2 medium 2 hard
TOTAL	71	12				

Table 6.7 provided insight into the following three categories of engagement: 1) attempts status, 2) students' performance and 3) question quality.

1) Attempts status

Table 6.7 shows that students did not submit their answers in 12 out of 71 attempts (17%). A look at the Grade centre revealed that the system recorded this as an *attempt in progress* and could not allocate a mark (see Figure 6.1).

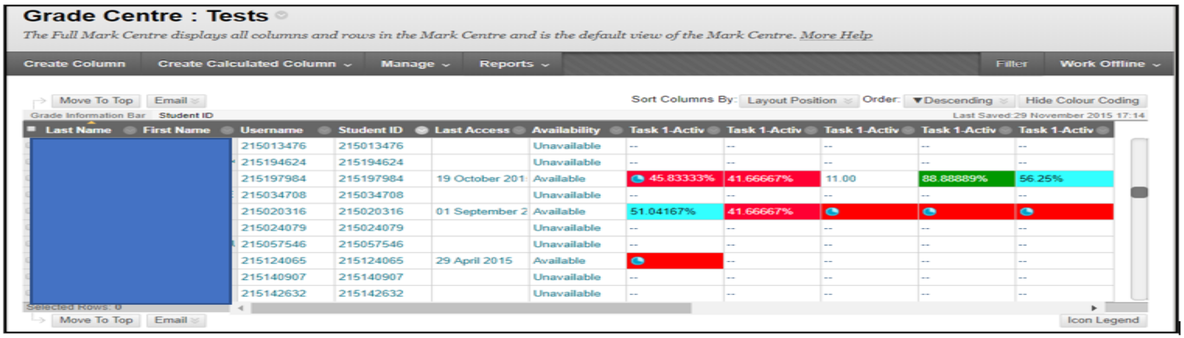


Figure 6.1: Example of Attempt in progress.

This suggested that these students needed a reminder or caution not to forget to submit answers.

2) Students' performance

Students' performance was not good since the average score in each activity was below the 60% targeted. This could be due to the poor quality of the e-tutorial activities/items. Moreover, the high average engagement time in Activity1despite this being the simplest (*researcher opinion*), with three good, medium difficulty questions, was also a concern. These were two design considerations needed in Cycle 2.

3) Questions Quality

Table 6.7 indicates that there were no questions in Activities 1, 3, 4 and 5 that could be poor discriminators of student performance. However, there were two areas of concern. Firstly, the presence of four hard questions was a sign of the suspected poor quality of these questions. These questions needed to be reviewed. Secondly, no data for Activity2 indicated that there were no attempts on this activity or that the system could not analyse the multiple-choice-type questions set in Activity 2. Activity 2 required special attention to determine why no student attempted this activity.

6.2.7.3 Attempts statistics

The Attempts statistics (section 4.2.4(4)) presented information on the overall quality of an Activity regarding score information in the individual questions. For each question in an Activity, score information was categorised as: correct, partially correct, or unanswered, as shown in Figure 6.2 below.

Category	Attempt Count	Attempt Count as Percentage of Total
Total Attempts	11	100%
Unanswered Attempts	2	18.182%
Correct Answer	4	36.364%
Partially Correct Answer	4	36.364%

Figure 6.2: Example Attempts statistics

Table 6.8 presents a summary of Attempts statistics extracted for each activity.

Table 6.8: Summary of Cycle 1 Attempts statistics

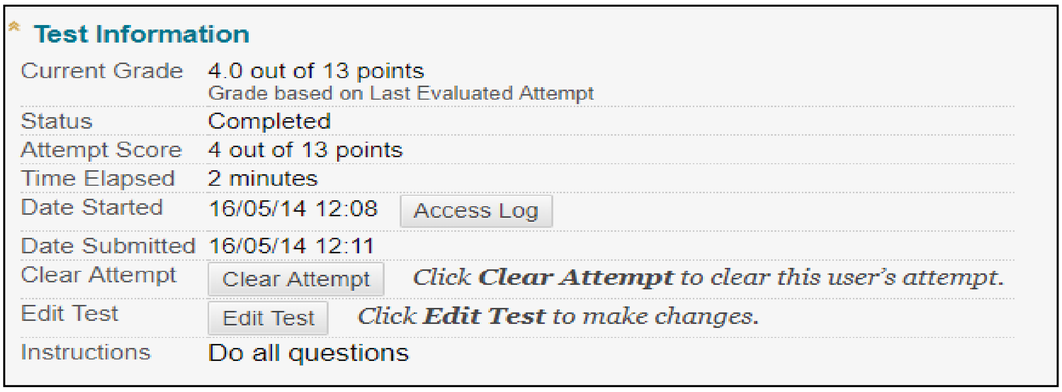
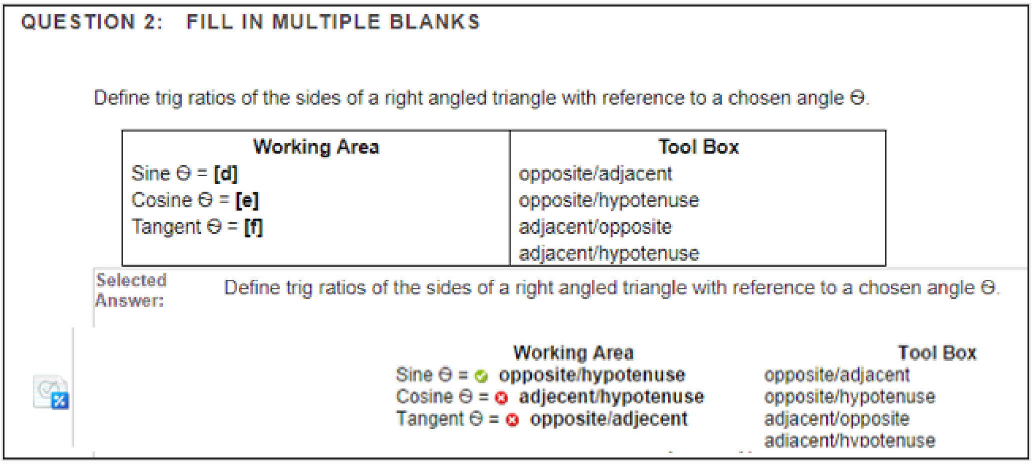
Activity	Activity1			Activity2			Activity3	Activity4			Activity5
	(attempts count per question per activity)										
Question	1	2	3	1	2	3	1	1	2	3	1
Attempts	14	14	14	No data	No data	No data	6	13	13	13	8
Correct	2	5	1				0	2	0	0	0
Partially correct	7	6	10				4	8	10	9	8
Unanswered	5	3	3				2	3	3	4	0

Table 6.8 provided insight into the quality of the individual questions per activity. Results indicate an average of 1 out of 14 (7%) correct attempts per activity. Moreover, 4 of the 8 (50%) questions that the LMS analysed had no correct attempts. This suggested poor students' performance in terms of correct answers despite the availability of possible solutions in the Toolbox. On the other hand, the students may have performed poorly because of the poor answering/marking interface articulated in Table 6.6. This exposed additional design considerations needed in Cycle2.

6.2.7.4 System responses

Examples of system responses in the activities were accessed via the attempts function of the grade centre. Table 6.9 indicates two types of feedback that were afforded by the system. The system indicated the overall performance feedback in the form of marks obtained, status, the time elapsed and correct or incorrect answers to each question.

Table 6.9: System responses

Focus area	Observation
1. LMS feedback	1. 1 Example of Performance feedback showing marks obtained, status, the time elapsed etc. 
	1.2 Example of correct/incorrect answers in each question 

The results indicate system feedback was given at the end of each activity. The results suggested an absence of immediate, question-by-question feedback to guide the students as they worked. This was a design weakness and needed consideration in the design and implementation of Cycle 2.

6.2.8 Summary of Key Results

Level-one analysis of regularly occurring insights into student engagement identified suggested the following local themes:

1) Learning Outcomes: students' performance, students' errors.

2) Student actions: student reading, student strategy, social interaction.

3) Student experiences: frustrations, satisfactions.

4) System use: system affordances, challenges while using e-tools, and system shortcomings.

1) Learning outcome (student performance, student errors)

- Results indicate an average of 7% correct attempts per activity. Moreover, 4 of the 8 (50%) questions that the LMS analysed had no correct attempts (section 6.2.7.3).
- Students were consistently marked wrong by the system. In some cases, multiple attempts on the same question remained wrong (section 6.2.3(2)).
- While this suggested a lack of understanding, in some of these cases, the students may have answered correctly but were marked wrong by the system due to student errors (e.g., spelling or typing mistakes, or using the wrong format for the correct answer) (section 6.2.7.1(2)). However, the problem could have been due to students learning orientation or e-tutorial design limitations, as discussed below.

2) Student actions (student reading, student strategy, social interaction)

- Student reading: the results suggested that students were more interested in doing calculations than studying the content resources. They did not review the content resources (section 6.2.3(1)). Some thought they knew the topic (section 6.2.3(4)).
- Rough work strategy: while working out tutorial questions students, they used rough work as a strategy to recall knowledge and to get an idea of how to complete the activity. They preferred to work out the tutorial questions on paper and then input their answers into the computer (sections 6.2.3(1).
- Support from peers: when students experienced technical or academic challenges, they asked for help from peers or tutor (sections 6.2.6(1)

3) Student experiences: (frustrations, satisfactions)

- Frustrations: students experienced some disappointments while using the e-tutorial. This occurred when they faced challenges while using the e-tutorial. Some students were repeatedly marked wrong by the system (section 6.2.3(4)), found filling in the blanks puzzling (section 6.2.3(2)), or encountered some shortcomings in the set-system-answers; for example, abbreviations were not catered for, and some were wrong (section 6.2.3(3)).
- Satisfactions: students experienced some positive reactions toward the system. Despite technical or academic challenges, students found the e-tutorial interesting to work with. Most students felt confident and satisfied while working with the e-tutorial. They

thought the e-tutorial was interesting, informative, and easy to work with (sections 6.2.6(1)).

4) System use (affordances, challenges while using e-tools, and system shortcomings)

- System affordances: the LMS test tool was used to present content resources and tutorial questions, providing space for answering the tutorial questions, marking tutorial questions, and conveying results to the student (sections 6.2.7.1).
- Challenges while using e-tools: some students experienced challenges while using the e-tutorial to do things such as how to fill in the blanks (section 6.2.3(2)).
- System shortcomings: restrictions in set-system-answers. There was no provision for abbreviations, alternative answers, typing mistakes or alternate ways of arriving at the answers (sections 6.2.3(3); 6.2.6(3); 6.2.7.1); 6.2.7.3(1)).

6.2.9 Evaluation of Results

Evaluation informed the decision process by providing an interim data analysis (see section 4.3.2.2). The evaluation process involved a contradiction analysis (see Section 3.3.4), addressing the inconsistency between original design objectives or conceptions of the e-tutorial and the actual use during testing as the criteria for evaluation.

6.2.9.1 Contradictions' analysis

These were mainly primary contradictions found within three components of the e-tutorial activity system, i.e., object, subject, and tool.

1) Object

The design objective of the e-tutorial was to assist students in learning through reviewing content presented in multimedia resources and to test their understanding by completing the accompanying tutorial questions. Students' performance was taken as a success indicator of e-tutorial outcome (see section 5.2.1(3)). The goal was to achieve 80% correct attempts per activity. However, contradictions occurred within the element *object* when the goal was not achieved. Students' performance in Cycle 1 indicated that only 1 out of 14 (7%) correct attempts per activity was achieved (6.2.7.3)). The students were consistently marked wrong by the system due to issues such as spelling errors, typing errors or using the incorrect format for the correct answer (6.2.7(2)). However, these errors could also be due to errors in the set-system-answers (6.2.7(1)). In other words, in some of these cases, the students may have answered correctly, but the system did not recognise their responses as correct.

2) Subject

The initial design assumptions and learning process model (see section 5.2.1) assumed that the students would first review content to access relevant knowledge and then use the acquired knowledge to answer the tutorial questions. By design, students were required to complete the tutorial activities (to improve trig knowledge and skills) using the e-tutorial (tool). However, contradictions occurred within the element *subject* when students exhibited some unanticipated attitudes and behaviour. Few students reviewed the introduction (6.2.4(1)) or reviewed resources (6.2.3(1)). It appeared that the students preferred to do/try tutorial problems first (6.2.3(1)). This suggested that the initial design assumptions and learning process model did not adequately represent the actual learning process.

3) Tool

The purpose of the e-tutorial system was to facilitate the learning processes. However, student responses revealed contradictions within the element *tool* in the form of shortcomings in the tutorial questions and the system. There was no room for partial credit in questions requiring multiple steps, where only space for one had been created. In addition, there was no provision for typos or alternative answers, and for some questions, the required answer format was too constraining (6.2.7(1)). As a result, some of the correct answers were marked wrong by LMS due to unfitting presentation or notation. Moreover, the LMS provided feedback only at the end of the activity, so students were not aware of their mistakes till the end (6.2.6(4)).

4) Secondary contradictions

Some secondary contradictions were also encountered between the subject and tool components of the e-tutorial activity system. These contradictions manifested as challenges or difficulties faced by students while using the system, e.g., filling the blanks (6.2.3(2), correcting mistakes (6.2.3(2), and consistently marked wrong by LMS (6.2.7(1)). These students had some deficiencies in how to use the e-tutorial tools.

6.2.9.2 Critical issues in the e-tutorial

1) Learning outcome

Taking students' performance as the success indicator of the e-tutorial outcome. Insights from the summary of key results indicated a low level of success (section 6.2.8(1)). The performance objective of a success rate of 80% per activity was not achieved. While this suggested a lack of understanding, other problems could have constrained the learning engagement process due to students learning orientation or e-tutorial design limitations, as discussed below. These were additional design considerations needed in Cycle2.

2) Learning orientation

The issue here was that students did not review the resources. Insights on student actions suggested that most students appeared to spend more time doing tutorial questions than reviewing resources (section 6.2.8(2)). However, when they got stuck, they asked for assistance from peers or tutor. This suggested a need to motivate the students to review resources.

3) Learning engagement

The very low correct attempts per activity observed above could have been due to system design limitations that constrained the learning engagement process. The contradiction analysis revealed system design problems in the following sections of the e-tutorial; Introduction item, Objectives item, Set-system-answers, and System use.

- Introduction: The issue here was students did not review the introduction.
- Objectives: This issue was that students' self-evaluation appeared inaccurate.
- Set-system-answers: The issue here was that in some of the set-system-answers to the tutorial questions, the system did not allow flexibility for marking (the acceptance and evaluation of responses).
- Challenges system use: This adaptation was made because novice computer users found it difficult to use the system. They experienced challenges such as filling in the blanks and correcting mistakes.

Resolving these problems was critical for the design considerations needed in Cycle2.

4) Summary of Critical issues identified from Cycle 1

Table 6.10 shows a summary of the critical issues in the e-tutorial that emerged from the data of the student's interactions with the system, as discussed in the sections above. The evidence of these issues in the data and its source(s) are also recorded in the table.

Table 6.10 Summary of Critical issues: Cycle 1

Original design	Issues arising	Possible causes	
Conceptions/objectives	Contradictions	Evidence	Data source
Learning outcome			
1. Performance The target success rate was 80% per activity.	The performance objective of a success rate of 80% per activity was not achieved.	On average, only 7% of correct attempts per activity were achieved	LMS generated data
Learning orientation			
1. Review of resources The purpose of this item was to enable students to learn through a review of the content presented in multimedia resources.	Students did not review resources.	No interaction with multimedia resources	Observation Screen capture video
Learning engagement			
(Design Limitations)			
1. Introduction This item's purpose was to give students an overview of the tutorial by reading the Introduction.	Students did not review the introduction.	No interaction with Introduction	Observation Screen-capture
2. Objectives The purpose of this item was to present the topic's content and enable students to evaluate self-knowledge about the topic.	Students' self-knowledge of what they knew appeared inappropriate.	Students' self-evaluation inaccurate	KWL questionnaire
3. Set-system-answers This is the answer the system checks responses against	Restrictions in set-system-answers; Students consistently get answers that the system identified as incorrect	i) No room for partial credit; Question requires multiple steps but has space for one ii) Required format too constraining iii) No provision for typos iv) No provision for alternative answers	Student responses
System use			
5. Challenges in system use	i) No immediate feedback	LMS affords feedback only at the end of the activity	LMS generated data
	ii) Students encountered difficulties while using the system	Novice users found it challenging to use the system, such as: filling the blanks and correcting mistakes	Student responses Interview

To resolve these issues, improvements were made to the e-tutorial system before Cycle2. The review process is discussed in section 6.3.1.

6.3 Cycle2 Results

The evaluation results in Cycle 1(see section 6.2.8) indicated several issues in the e-tutorial design. Cycle 2 involved making changes to the e-tutorial to correct these issues. The following section, the review process, recaps how and why the e-tutorial system was changed.

6.3.1 Review Process

The evaluation of results in Cycle 1 (see section 6.2.7) provided reasons for change and development that emerged from each data modality. The review provided the direction for transforming and improving the e-tutorial system. This section discusses the changes made during the transformation. It describes the issues addressed, the changes made to the tutorial, justifications for the change (how it is expected to overcome the issue) and objectives for the change (in terms of what response it is expected to generate).

6.3.1.1 Overview of Tut 2

Results from Cycle 1 were used to review, make decisions, and refine the system. The product was Tut2.

1) Learning outcome

The issue was that very low (on average, only 7%) correct attempts per activity were achieved. This could have been due to i) lack of understanding or ii) students did not review resources, iii) difficulties in using the system, or iv) shortcomings in the set-system-answers. The redesign idea to address lack of understanding was to use assessment for learning to improve student achievement (section 2.5.5). To achieve this objective, rehearsal problems were added to the e-tutorial as short quizzes (Quizlets). The aim was to make it possible for students to check their understanding on the go and enhance their learning. The redesign ideas to address other issues are discussed in the following sections.

2) Learning orientation

This responded to the issue that students did not review resources. The redesign idea was to add Quizlet feedback directing students to review resources and try again. The objective was to motivate the students to review resources as they worked on the Quizlets. The chances to try the same question again were limited to three to facilitate progress.

3) Learning engagement

Four design changes were made in the transformation to Tut 2, aimed at rectifying the four system design limitations that might have constrained the learning engagement process in Cycle 1.

- Introduction: The issue here was students did not review the introduction. The redesign idea was to make the introduction an interactive presentation by allowing flexible access to the different pieces of information. The objective was to make reading the introduction engaging so students would spend more time reading. However,
- Objectives: This issue was that students' self-evaluation appeared inaccurate. The redesign idea was to introduce a pre-test to assist students in identifying knowledge gaps based on the results of the pre-test and so realise the need to work through the tutorial.
- Set-system-answers: The issue here was that in some of the set-system-answers to the tutorial questions, the system did not allow flexibility for marking (the acceptance and evaluation of responses). There was no room for partial credit where questions required multiple steps and no provision for typing errors or alternative answers. The redesign idea was to re-format the system to appropriately deal with all possible solutions.
- Challenges system use: This adaptation was made because novice computer users found it difficult to use the system. They experienced challenges such as filling in the blanks and correcting mistakes. The redesign idea was to add hints in Quizlet feedback, directing students to ask for assistance from the tutor. The objective was to help the tutor to identify and assist struggling students.

6.3.1.2 Summary Review process

Table 6.11 shows a summary review process of the critical issues that emerged from the results of Cycle 1.

Table 6.11: Summary of the Review process

Issue identified	Change made	Justification	Objective
(And how it was evident in the data)	Action	How it is expected to overcome the issue	What response is it expected to generate
Learning outcome			
Performance: Lack of understanding Very low correct attempts per activity were achieved. (Observation; section 6.2.3) (Column statistics; 6.2.7.3)	Introduce Quizlets	as rehearsal problems	80% success rate
Learning orientation			
Review of resources Students did not review resources. (Observation; section 6.2.3) (Screen-capture; 6.2.4)	Introduce Quizlet feedback.	Direct students to review resources and try again.	Students review resources as they work.
Design changes			
1) Introduction item			

Issue identified	Change made	Justification	Objective
Students did not review the introduction (observation; section 6.2.3)	Make it an interactive presentation by linking clickable tabs to different presentation sections.	Flexible access to the different pieces of information	Make reading the Introduction interesting. Students spend more time reading.
2) Objectives item Students' self-evaluation inaccurate (KW questionnaire, 6.2.20	Introduce pre-test	Assist students to i) identify knowledge gaps from the results of the pre-test ii) realise that they need to do tutorial	Students make accurate self-evaluations of knowledge about the topic.
3) Set-system-answers (Student responses; 6.2.7.1) i) No room for partial credit; Questions require multiple steps but have space for one	Break up answers into smaller sections; a minimum of 3 sections per question.	Create space for multiple steps	System to allow partial credit
ii) No provision for typing errors	Re-format answers Explore all possibilities	Include all possible answers	To allow flexibility in marking to cover typos and alternative answers.
iii) No provision for alternative answers			
iv) Required format too constraining	Change question to regular answer format Add example of required answers	Simplify answer format	To make the answering straightforward
4) Difficulties in using the system (Observation; section 6.2.3) i) Novice users found it difficult to use the system, challenges: filling the blanks and correcting mistakes	Add hints directing students to ask for assistance.	Facilitate students to ask for assistance	To enable the tutor to identify and assist struggling students.
ii) LMS affords feedback only at the end of the activity	Add Quizlets feedback	Immediate feedback	To guide students as they work.

6.3.2 Student Profile

The student profile questionnaire (see Appendix 12.1) was completed by thirty-eight students of a class of forty (class listed). It indicated an almost equal number of male (52.6%) and female (47.4%) students.

Most of these students (63.2%) were between 17 and 20 years old. Of the rest, 23.7 % were between 21 and 23, 7.9 % were between 24 and 26 and 2.6 % were more than 26. Most of these students (50%) had completed their matric the previous year; others had one (18.4%), two (15.8 %) or more than two gap years (15.8 %). Most of these students rated their computer experience as Intermediate (60%), and others indicated Novice/Beginner (30%) or Expert user (10%).

Thirty-one (75%) students of the 40 responded to the call to test the system. The students were asked to do a series of tasks using the e-tutorial during the Mathematics tutorial period. They were given no training but had access to other resources that they would have in the regular classroom environment (e.g., a scientific calculator). Also, the researcher was available to be consulted as a tutor and answer any questions the students may have had.

6.3.3 Pre-test Attempts Statistics

Cycle2 started with a pre-test followed by Know-Want to learn form. The pre-test consisted of 10 multiple choice questions and 9 show work questions, formatted as fill-multiple-blanks to emulate the working steps. Figure 6.2 shows a summary of pre-test results.

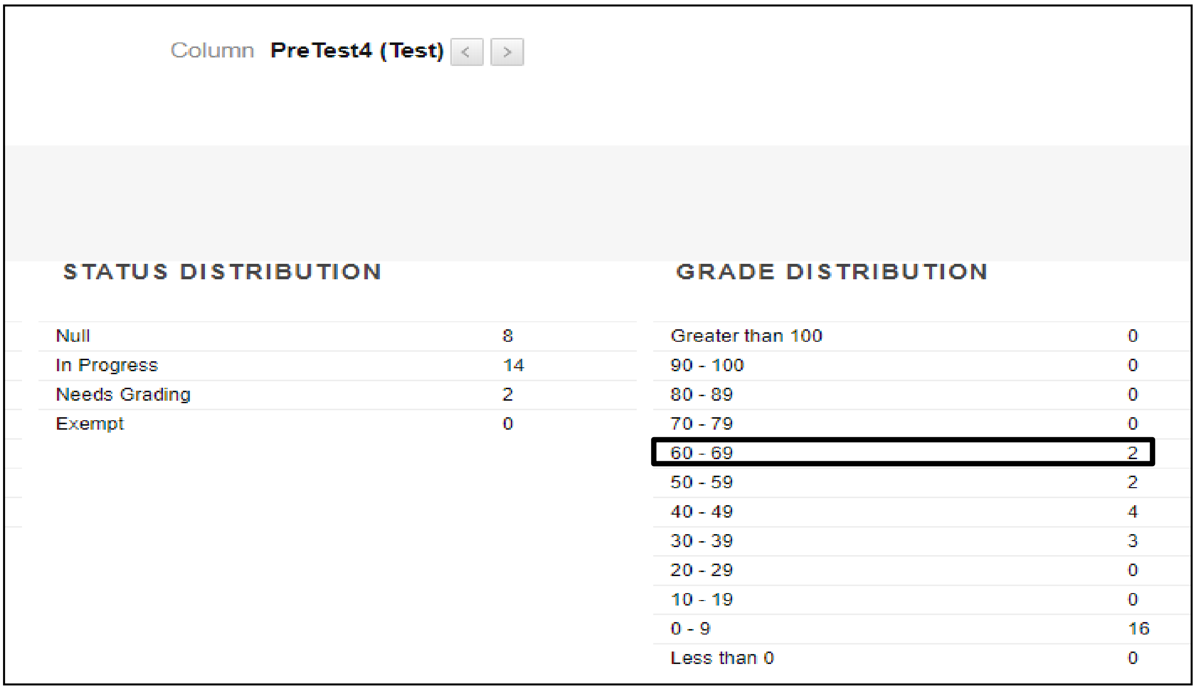


Figure 6.3: Cycle2 Pre-test attempts statistics

Results indicate that 27 attempts were made on the pre-test. Only two students out of twenty-seven who did the pre-test managed to get a mark greater than 60%, 7 attained between 30% and 50% and 16 scored between 0% and 9%. This suggested that 85% of the students could have benefitted from revising the basic trigonometry covered by the e-tutorial system. However, some of these results could have been correct responses that the system did not recognise as valid.

6.3.4 Know-Want to learn questionnaire

The Know-Want to learn questionnaire was completed by 31 students out of 40 in the class. Results are summarised in Table 6.12.

Table 6.12: Results from the Know-Want to learn questionnaire

	1 I want to learn this topic	2 I want to revise this topic	3 I know this topic partially	4 I know this topic well	5 I know this topic very well	TOTAL
1. Identify sides of a right-angled triangle with respect to a given angle	7	12	6	3	3	31

2. Define trigonometric ratios for angles in right-angled triangles	5	15	7	2	2	31
3. Use trigonometric notation e.g., sin A	8	8	5	8	2	31
4. Use a calculator to find approximations of the trigonometric ratios of a given angle measured in degrees	6	11	2	8	4	31
5. Use a calculator to find an angle correct to the nearest degree, given one of the trigonometric ratios of the angle	5	10	4	10	2	31
6. Use the Pythagoras theorem to find a missing side of a right triangle.	8	1	1	12	9	31
7. Select and use appropriate trigonometric ratios in right-angled triangles to find unknown sides.	2	11	7	7	4	31
8. Select and use appropriate trigonometric ratios in right-angled triangles to find unknown angles	1	14	3	11	2	31
9. Solve problems involving the use of right-angle trigonometry	5	11	4	9	2	31
TOTAL	47(17%)	93(33%)	39(14%)	70(25%)	30(11%)	279

Results from the Know-Want to learn questionnaire indicate that, overall, there was an even split (given that the number of responses was odd) between the number of responses in which students judged that they knew the topic (139(49.8%)) and those who wanted to learn or revise the topic (140(50.2%)). This is inconsistent with the pre-test results (section 6.3.3), which indicated that 70% of the students scored below 39% in the pre-test. Results suggest that the pre-test could assist the students in identifying their learning needs more appropriately on this topic (before starting the tutorial) than the Know-Want-to-learn questionnaire.

6.3.5 In-class Observation

As in Cycle 1, Cycle2 observation focused on how students engaged with the e-tutorial activities and their challenges. The observation notes summarised the researcher's encounters with the twelve students who asked for assistance when they experienced challenges. Results are summarised in Table 6.13.

Table 6.13: Cycle 2 Observation data

Focus area	Observation
1. Student Engagement	1.1 S1 asked for assistance with the Introduction presented on opening Task1 (*student shown how to navigate presentation*) 1.2 after the tutor's help, the student successfully clicked on Tabs to go to another page/section of the presentation, 1.3. however, this student spent a very short time on the Introduction (*approximately 1min*). 1.4 No other student asked for assistance on how to review the Introduction 1.5 Twelve (12) students asked for assistance with Quizlet questions; all of these students had worked out the questions on paper (*assisted on how to copy/enter answers to the computer).* 1.6 S5 did Activity1 Quizlet three times; student comment "did not use video" (*why*) "confusing and too long" (*student shown how to play the video; pause, rewind, or skip*) 1.7 S6 did Activity1 Quizlet two times; student comment, "I watched the video and read the notes, how do I do Quizlet again" (*student shown how to re-do Quizlet)* 1.8 Ten (10) students asked for assistance with tutorial questions, 1.9 these students worked out the tutorial questions on paper and then copied them to the computer. (*assisted on how to enter answers in the computer or correct mistakes; see 2.7)*
2. Challenges	2.1 S1 needed to be shown how to click on Tabs to go to another page/section of the presentation 2.2 In four cases (S2, S5, S6, S10), the YouTube link presented a connectivity error message that the source cannot be trusted. These students could not access the resources. Students asked for assistance, but the tutor could not fix the problem immediately. 2.3 S5 asked for assistance on how to play the video *(how to look for information*) 2.4 S1, S4, S5 found Quizlet a little confusing, did not know how to start it. 2.5 S5, S6 could not figure out how to repeat Quizlet (*after failing)*. 2.6 S3, S7 noted that Quizlet answers seemed to be wrong (*due to a spelling error*), questions were not clear 2.7 S1, S8, S9, S10, S11, S12 needed assistance with how to correct mistakes when answering tutorial questions.
3. Technical problems	3.1 The system did not provide feedback on whether students read the introduction. 3.2 LMS did not pick up students' responses in the Quizlets.

In-class observations provided insight into the following four categories of engagement: 1) student actions, 2) system use, 3) system shortcomings, and 4) student experience.

1) Student actions

In-class observations suggested that despite the assistance on how to interact with the presentation (1.1, 1.2, 2.1), students spent a very short time on the Introduction item (1.3). This suggested that students may not have engaged effortfully and conceptually with the introduction as expected. Also, students spent some time working out the Quizlet questions on paper and then copied their answers to the computer (1.5). Similarly, students worked out the tutorial questions by doing rough work on paper and then copied to the computer. Some students needed assistance correcting mistakes when copying answers to the computer (2.7). The student actions suggested that these students were more engaged with the Quizlet and tutorial questions than with reviewing the introduction.

2) System use

Results suggested that at least 12 students worked out the Quizlet questions (1.5). The Quizlets functioned as rehearsal problems (1.6; 1.7), and in at least one case (1.7), this motivated the student to review the resources. However, the students faced several challenges with the Quizlets; some found it a little confusing to work with the Quizlets. One did not know how to start it (2.4), and another student could not figure out how to repeat the Quizlet after failing (2.5). Others found the Quizlet questions unclear, and the answers seemed wrong (2.6). These results suggested that the Quizlets were a positive contribution but still had issues to be addressed.

Observation data also suggested that some students succeeded in accessing/opening the videos (1.6; 1.7) but found the video too long and needed assistance with looking for the required information (1.7). Results suggested a need to change the resources' format to make it easier for students to access and review content.

3) System shortcomings

Results indicate that students tried to access YouTube videos. However, these presented connectivity errors in some cases (2.3), making the resources inaccessible. The results suggested a need for resources to be embedded within the LMS to avoid dependency on external sources.

From the tutors' perspective, the system did not provide feedback about whether students read the introduction and did not pick up students' responses to the Quizlets (3.1). Thus, vital information on students' engagement was missed. The results suggested a need for the system to provide the tutor with feedback/results indicating students' engagement with the Introduction item and working with the Quizlets.

4) Student experience.

Some students were frustrated with the system resources (1.6; 2.2). It may have been helpful for such students to be identified and supported by the tutor.

6.3.6 Screen-capture Data

In line with the ethical considerations (see section 4.5.3), students were in control of screen capture software and were encouraged (not forced) to switch it on. In Cycle 2, only two students used the screen capture software. Results are summarised in Table 6.14 (transcripts are shown in Appendix 8). Screen-capture video data provided insight into the following student actions. Student1 did not look at the resources while Student2 interacted with the presentation (1.1 and 1.2), but this interaction lasted for only 6 seconds (*skim-reading*?) (1.4). The results suggested students did not engage effortfully and conceptually with the introduction and resources as expected. This indicated that the students needed to be motivated to engage with the Introduction and resources.

Table 6.14: Observations from screen-capture video

Focus area	Observation
1. Student Engagement	1.1 S1 went straight into answering the tutorial questions. 1.2 S1 No multimedia resource was opened. 1.3 S2 Opened YouTube video. 1.4 S2 Interaction with the presentation lasted for only 6 seconds
2. Challenges	2.1 The system did not provide feedback on whether students read the introduction. 2.2 The resource link showed a connectivity error message that the source could not be trusted.

6.3.7 Interview Responses

In Cycle2, one session of interviews was conducted. Two (2) students agreed to be interviewed. Interviews were recorded and later transcribed, as shown in Appendix 4. These interviews were semi-structured, comprising predetermined questions on the teaching and learning needs of the students, the challenges they faced and their perceptions, attitudes and experiences in the current teaching and learning situation. The results are summarised in Table 6.15.

Table 6.15: Summary of Interview responses.

Focus area	Observation
1. Student Engagement	1.1 S2: "I did not use notes". (*why*) "because I thought I know this." 1.2 S2: "I do read the notes, but sometimes my answers were wrong; I do not know what is wrong". 1.3 S1: "you must write the full answer and then copy it to the computer so that you know you are writing the perfect thing." (Do you think the system can be useful?) 1.4 S1: "Some students may have taken 1 or 2 years gap-year. So, WiSeUp helps these to revise". 1.5 S2: "When a lecturer is lecturing in the class, they do not go step by step. They take that you know these things. So in WiSeUp, we do revision."
2. Challenges	2.1 S1: "I used abbreviations when I looked at the answers that required the full word." 2.2 S2; "I do not understand the questions, sir. the questions were not clear." 2.3 S1: "Sometimes the answer (*system*) was wrong" *(how did you know that it was wrong)?* "I checked many times". 2.4 S1: "I could not see the following questions. 2.5 some of the questions were at the corner or the bottom". 2.6 S1: "In other computers, there are no full questions." 2.7 S2: "I find the side, but when I see the answer that I wrote is not the same as they are writing." 2.8 S1 "you must tell us to put to 2 decimal places or three significant figures like that…."

Interview responses provided insight into the following four categories of engagement: 1) student actions, 2) system use, 3) system shortcomings, and 4) student self-evaluation.

1) Student actions

Interview responses indicate that students adopted a strategy of writing the full answer (of the Quizlet/tutorial questions) on paper and then copying this to the computer to make sure they are "writing the perfect thing" (S3). Interview responses also indicate that while one student did not use the resources (1.1), another read the notes "but sometimes the (*student*) answers were wrong" (1.2) (i.e., *were marked as incorrect by the system*). The student actions suggested that these students were engaged but got wrong answers because of a lack of understanding (2.2). From this, it can be seen that reading the notes does not imply that the student would fully understand the topic.

2) System use

The students faced several challenges while using the system. For example, sometimes, the system identified the answer they entered as incorrect, even though it was mathematically correct (2.3; 2.7). This could have been due to technical issues, such as using abbreviations instead of the full word (2.1). The results suggested a need for the system to allow still more flexibility for the entry of answers and to accommodate typos and abbreviations.

3) System shortcomings

Interview responses indicated some system shortcomings in the tutorial question configuration. Some students could not see all the questions (2.4), and some of the questions did not appear normal on the screen (2.5; 2.6). Sometimes the set-system-answer was wrong (2.3), or the system did not specify (in the tutorial questions) the required number of decimal places (2.7). The need to improve the system and reconfigure questions to facilitate this learning was evident.

4) Student self-evaluation.

As seen from the students' responses in the Know-Want-to-learn questionnaire (section 6.3.4) and the interview (1.1), some students felt that they knew basic trigonometry. However, the two students who were interviewed believed, even though they considered themselves to know basic trigonometry, the e-tutorial could help in revising basic trigonometry (1.4; 1.5), for example, in cases where a student may have taken a gap year (1.4) (section 6.3.2). The results suggest that the students found the e-tutorial challenging but useful.

6.3.8 Journal Responses

As in Cycle 1, all students were encouraged (not forced) to complete a learning journal (Section 4.2.1) detailing their experiences during the tutorial. In Cycle2, 14 journal responses were collected by the system. Results are summarised in Table 6.16. It shows the sum of agreed or strongly agreed responses per item expressed as a percentage and some of the answers to the open questions.

Table 6.16: Summary of Journal responses

Focus area	Observation
1. Student Engagement	1.1 Task was informative 79%, exciting 86%, interesting 86% 1.2 e-tools made the task easy 72 %, quick 72% 1.3 While doing the task, felt confident 72%, satisfied 64% 1.5 Asked for help from tutor 78%, peer 71 %
2. Challenges	(What did you find challenging when you were doing the task?) 2.1 "using the computer to solve the problem." 2.2 "want to know to use a computer." 2.3 "HOW DO I GET MY RESULTS." 2.4 "naming sides of a right-angled triangle." 2.5 "finding the missing angle." 2.6 "Lack of understanding some few things." 2.7 "I couldn't understand the question more clearly."

Journal responses provided insight into the following two categories of engagement: 1) student experience and 2) System use.

1) Student experience

Journal responses indicate that, on average, the majority (more than 70%) of students found the e-tutorial informative, easy, and quick to use (1.1; 1.2), and they felt confident and satisfied (1.3). In case of problems, students asked for help from tutor or peers (1.4).

2) System use

The answers to open questions indicate 3 significant issues that needed to be addressed. Students experienced some challenges with 1) using the computer (2,1, 2.2, 2.3), 2) basic trigonometry skills (2 4; 2.5) and some questions were not straightforward (2.6; 2.7).

Journal responses suggested that, although most students had a positive experience while working on the system, struggling students may have benefitted from direct assistance from the tutor with using the computer. Additionally, finding questions unclear was a symptom of a lack of understanding of the basic trigonometry concepts. Results suggested a need for improvements in the system to facilitate this learning and ask questions more clearly.

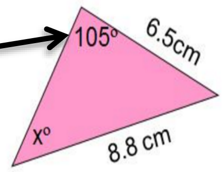
6.3.9 LMS Generated Data

In Cycle2, four data sets were extracted from the grade centre of the LMS: 1) Students' work samples, 2) Item analysis, 3) Column statistics and 4) System responses.

6.3.9.1 Student work samples

Several issues relating to answering tutorial questions were identified from students' work samples (answers). These are articulated in Table 6.17 below.

Table 6.17: Issues relating to the answering of tutorial questions

Issue description	No. of cases	Examples
1 Students' mistakes 1.1 Incorrect spelling Activity 1 (question 1) Activity 4 (question 2)	 7(out of 20 attempts) 4(out of 10 attempts)	✖ hypotenuse Given: the lengths of the sides ✖ **adjacemt** to t he angle, and the ✖ **hypotenus** side.
Observation1: students' answers were marked wrong due to spelling error		
1.2 Copying values incorrectly Activity 5	3(out of 9 attempts)	Working area Find the value of **x** in this triangle. Sinx = ✖ sin108 / ✔ 6.5 ✔ 8.8 Sinx = ✖ 6.5sin108 / ✔ 8.8 x = ✖ 45 
Observation2: students' answers were marked wrong due to a slip in copying given values		
1.3 Not squaring Activity 2,	5(out of 13 attempts)	**Working Area** Calculate the value of KL in Δ KLM (nd KM = 24 KL^2 = ✔ KM^2 + ✔ LM^2 KL^2 = ✔ 24^2 + ✔ 8^2 KL^2 = ✖ 24 + ✖ 8 ← KL^2 = ✔ 640 ∴ KL = ✖ 25.2
Observation3: student did not put correct answers after squaring but got it right in the next step. =>steps in student answer did not correspond with set-system-answers => 3rd step can be omitted		
2 Challenges 2.1 Rounding answer Activity 2		**Working Area** Calculate the value of KL in Δ KLM (nd KM = 24 KL^2 = ✔ KM^2 + ✔ LM^2 KL^2 = ✔ 24^2 + ✔ 8^2 KL^2 = ✖ 24 + ✖ 8 KL^2 = ✔ 640 ∴ KL = ✖ 25.2 ←
Observation4: rounding precision chosen by the student may not be the level of precision used for marking =>required level of precision is not clear and needs to be specified in the question		
2.2 Solving simple equations Activity 3	3(out of 10 attempts)	Therefore tanA = ✖ **OPPOSIT/ADJACENT** tan62 = ✔ **3/X** x = ✖ **TAN62**/✖ **3** x = ✖ **5.6** to 1 decimal place
Observation5: multiplicative inverse was not used.		

Student work samples suggest the following issues relating to students answering tutorial questions: 1) student errors and 2) system use, and 3) set-system-answers.

1) Student errors

Student work samples indicated three types of student errors, spelling (1.1), not squaring (1.3) and copying values incorrectly (1.2). Results suggested that these errors could have affected students' performance. This indicated that students needed hints or examples at respective questions about checking their answers for mistakes before submitting. However, these results could have been more accurate than suggested (see section 3 below).

2) System use

Students also experienced some mathematical challenges. For example, an error due to rounding (1.3) may have been an activity error since the level of precision was specified in the question. The results suggested that students need reminders at respective questions about the required level of precision. However, if the level of precision is not specified in the question, the system should have the flexibility to allow students to choose the precision they prefer.

3) Set-system-answers

It was noted that students experienced some challenges when working out the tutorial questions (2.1; 2.2). The problem seemed to arise from the flaws in the set-system-answers. For example, steps in student answers did not correspond with set-system-answers (2.1). The results indicated a need to review the set-system-answers to remove the observed flaws.

6.3.9.2 Item Analysis

Cycle2 item analysis aimed to reassess the quality of the Activities items and the Tasks as a whole and to use this information to improve questions. Table 6.18 shows a summary of Cycle2 item analysis.

Table 6.18: Summary of Cycle2 Item Analysis

Activity	Attempts status		Average performance		Questions	
	Completed	In Progress	Time	Score	Discrimination	Difficulty
Task1-Activity1	17	7	02hr30min	25%	3 good	1 easy 2 medium
Task1-Activity2	35	2	02hr02min	79%	6 good	5 easy 1 medium
Task1-Activity3	10	3	00hr50min	25%	5 good	1 easy 2 medium 2 hard
Task1-Activity4	10	2	00hr20min	34%	2 good 1 fair	3 hard
Task1-Activity5	9	4	00hr40min	21%	1 good	1 hard
Task 2	30	2	01hr20min	46%	5 good	2 easy 2 medium 1 hard
TOTAL	111	20		38,33%		

Table 6.18 provided insight into the following three categories of engagement: 1) attempts status, 2) students' performance and 3) question quality.

1) Attempts status

Table 6.18 shows that in 20 out of 111 attempts (18%), students did not submit their answers, which were recorded by the system as *attempts in progress*. This result is close to the 17% recorded in Cycle 1, despite a caution to students not to forget to submit answers. This suggested a need to look for another way of solving this problem.

2) Students' Performance

Students' performance was not good since the average score in each activity was below the targeted 60%, despite improving questions in Task1-Activity 2. This could have been a symptom of challenges the students faced due to (among others) lack of flexibility in set-system-answers which resulted in some of the students' answers being marked as wrong by the system (section 6.3.7(3)), connectivity errors which made the resources inaccessible (section 6.3.5(3)), or shortcomings in the tutorial question configuration which caused some of the questions not to appear normal on the screen (section 6.3.7(3)).

3) Questions Quality

Table 6.18 indicates that there were no questions in all Activities that could be poor discriminators of student performance. However, the presence of five hard questions (judged as such by student results), while these questions were not hard when compared to the trig skills expected of the students in their course, was a sign of suspected quality issues in these questions (section 6.3.7(3)) which needed to be reviewed. Or the students' level of engagement was still too low and needed to be uplifted.

6.3.9.3 Column statistics

The Column Statistics displayed statistics for an Activity, represented by a grade centre column, showing how students fared on each Activity and how the grades were distributed. The aim was to see activities where the targeted pass rate was achieved.

Table 6.19 shows a summary of grade distribution, which displays how students fared in each activity.

Table 6.19: Summary of Cycle2 grade distribution

Task	Activity	Grade distribution (based on completed)		
		< 60%	> 60%	Success rate (%)
Task 1	1	11	6	50
	2	1	12	92
	3	3	7	70
	4	6	4	40
	5	2	7	77
Task 2	1	8	0	0

The results indicate a success rate of less than 80% in 5 out of the 6 activities, although 2 of the 5 had a reasonable performance with a success rate of 70%. The results suggested an improvement over cycle 1, despite the issues observed in section 6.3.9.2(2). However, Task 2 remained a challenge since all the eight students who attempted this task got less than 60%.

6.3.9.4 System responses

Table 6.20 shows an example of system responses in the form of Quizlet feedback.

Table 6.20: System responses

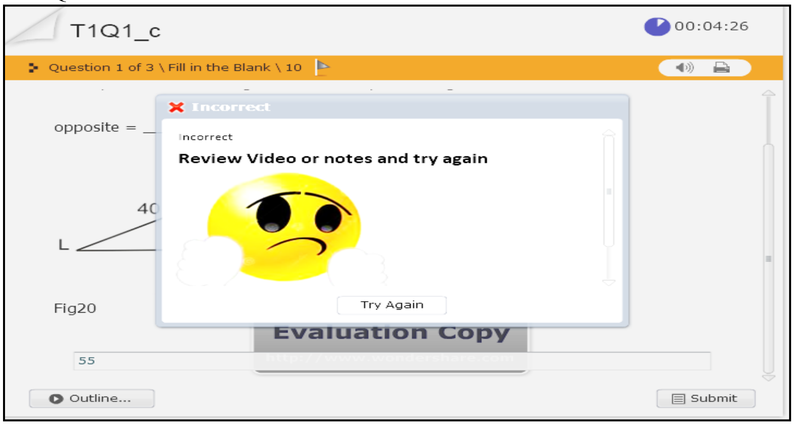
Focus area	Observation
1. LMS feedback	1.1 Introduction The system did not provide feedback on whether students read the introduction.
	1. 2 Quizlet feedback. 
2. Challenges	2.1 the LMS could not pick up the data from students' responses to the Quizlets.

Table 6.20 indicates another type of feedback that the Quizlets afforded; immediate, question-by-question level feedback by the system, as shown above (1.2). However, student actions (observed in 6.3.5(1.6)) suggested that some students struggled with doing the activities because they did not review the resources as directed by Quizlet feedback (1.2). In other words, the feedback might have been too general. The results suggested a need for more elaborate feedback that directed students to a relevant section in the resources.

6.3.10 Summary of Key Results

Level-one analysis of regularly occurring insights into student engagement identified suggested the following local themes:

1) Learning Outcomes: students' performance, students' errors.

2) Student actions: student reading, student strategy, social interaction.

3) Student experiences: frustrations, satisfactions.

4) System use: system affordances, challenges while using e-tools, and system shortcomings.

1) Learning outcome (student performance, student errors)

- Results indicate a success rate of less than 80% in 5 of the 6 activities was achieved. Two of the five had a reasonable performance with a success rate of 70%(section 6.3.9.3).
- This could have been due to student slip-ups such as spelling errors, incorrect information, or difficulty in solving simple equations with fractions (section 6.3.9.1(1)).

2) Student actions (student reading, student strategy, social interaction)

- Student reading: students did not engage effortfully and conceptually with the introduction and resources as expected (section 6.3.7(1)). They were more involved in doing Quizlets and tutorial calculations than studying the content resources (section 6.3.6).
- Rough work strategy: while working out the Quizlets and tutorial questions students, they used rough work to work out the questions on paper and then input their answers into the computer (sections 6.3.5(1); 6.3.7(1)).
- Support from peers: when students experienced technical or academic challenges, they asked for help from peers (sections 6.3.8(1)).

3) Student experiences: (frustrations, satisfactions)

- Frustrations: these occurred when students faced challenges while using the e-tutorial, using the computer, lack of basic trigonometry skills and some questions were not straightforward (sections 6.3.8(2)). Some students were frustrated with the system resources (sections 6.3.5(4)).
- Satisfactions: Journal responses indicate that, on average, the majority (more than 70%) of students found the e-tutorial informative, easy, and quick to use. And they felt confident and satisfied while working with the e-tutorial (sections 6.3.8(1)).

4) System use (affordances, challenges while using e-tools, and system shortcomings)

- System affordances: the e-tutorial system presented Quizlets, content resources and tutorial questions and provided space for answering these questions. These questions could also be marked, and results presented to the student (sections 6.3.9.1). The Quizlet also provided immediate, question-by-question level feedback directing students to review resources when they fail (sections 6.3.9.4).

- Challenges while using Quizlets: the students faced several challenges with the Quizlets; some found it a little confusing to work with the Quizlets. One did not know how to start it, and another student could not figure out how to repeat the Quizlet after failing. Others found the Quizlet questions unclear, and the answers seemed wrong. These results suggested that the Quizlets were a positive contribution but still had issues to be addressed (section 6.3.5(2)).
- System shortcomings:
    - YouTube videos presented connectivity errors in some cases, making the resources inaccessible (section 6.3.5(3)).
    - Tutorial question configuration caused some of the questions not to appear normal on the screen (section 6.3.7(3)).
    - Flaws in the set-system-answers (section 6.3.9.1(3))

6.3.11 Evaluation of Results

Evaluation informed the decision process by providing an interim data analysis (see section 4.3.2.2). The evaluation process involved 1) contradiction analysis of components of the e-tutorial activity system and learning environment, 2) an evaluation of the effectiveness of Cycle2 changes, and 3) identification of the critical issues to work on Cycle3.

6.3.11.1 Contradiction analysis

In analysing parts of the e-tutorial activity system, contradictions were found within three parts of the e-tutorial activity system. These were mainly primary contradictions found within three parts of the e-tutorial activity system, i.e., object, subject, and tool.

1) Object

As explained in section 5.2.1(3), the performance objective of the e-tutorial was to achieve a success rate of 80% per activity. Contradictions occurred within the element *object* when a success rate of 80% was achieved in only 1 out of the 6 activities. However, 2 of the remaining 5 had a reasonable performance with a success rate of 70% (section 6.3.9(3)).

2) Subject

By design, students were required to correctly complete the tutorial activities (to improve trig knowledge and skills) using the e-tutorial. However, contradictions occurred within the element *subject,* where some students were still getting wrong answers due to errors such as spelling, not squaring and using incorrect information. As well as mathematical challenges not directly related to trigonometry, such as solving simple equations with fractions (section

6.3.9(1)). Moreover, the students did not engage effortfully and conceptually with the resources as expected (section 6.3.7(1)).

3) Tool

In Cycle2, Quizlets were introduced as challenges and rehearsal problems to assist students in developing and refining their knowledge. However, observation and student responses revealed contradictions within the element *tool* in the form of system shortcomings. Some Quizlet questions were unclear, some answers seemed incorrect, and Quizlet feedback (directing students to review resources and try again) was not sufficiently clear and detailed. Moreover, the set system answers to some tutorial questions had flaws. For example, the rounding precision chosen by the student may not have been the level of precision used for marking.

6.3.11.2 Evaluations of Cycle2 changes

Cycle2 evaluations focused on the effectiveness of each of the six changes and their respective objectives, which were set during the review process. The result of each change was evaluated in relation to how well the objective was achieved in overcoming the issue.

1) Learning outcome

The issue was that very low success rates were achieved in Cycle 1. The redesign idea to address lack of understanding was to use assessment for and as learning to improve student achievement (section 2.5.5). To achieve this objective, rehearsal problems were added to the e-tutorial as short quizzes (Quizlets). Results indicate that a success rate of 80% was achieved in only 1 out of the 6 activities (section 6.3.9(3)), and 2 of the remaining 5 had a reasonable performance with a success rate of 70%. The results suggested an improvement over cycle 1, but the target performance was not achieved. The students were still getting wrong answers due to errors such as spelling, not squaring and using incorrect information. As well as mathematical challenges not directly related to trigonometry, such as solving simple equations with fractions (section 6.3.9(1)).

2) Learning orientation

This responded to the issue that students did not review resources. The redesign idea was to add Quizlet feedback directing students to review resources and try again. The objective was to motivate the students to review resources as they worked on the Quizlets. The results suggested that despite the Quizlet feedback, some students did not engage effortfully and conceptually with the resources as expected (section 6.3.7(1)). Quizlets were a positive contribution; however, issues were still to be addressed.

3) Learning engagement

Four design changes were made in the transformation to Tut 2, aimed at rectifying the four system design limitations that might have constrained the learning engagement process in Cycle 1.

- Introduction: The issue here was students did not review the introduction. The redesign idea was to make the introduction an interactive presentation by allowing flexible access to the different pieces of information. The objective was to make reading the introduction engaging so that students would spend more time reading. However, results suggested that interactive media alone was not enough to engage students. Students did not interact effortfully and conceptually with the introduction content (they spent a short on the item).
- Objectives: This issue was that students' self-evaluation appeared inaccurate. The redesign idea was to introduce a pre-test to assist students in identifying knowledge gaps based on the results of the pre-test and so realise the need to work through the tutorial. However, Pre-test and KW-questionnaire results did not match. This suggested a need to choose which of the two to use.
- Set-system-answers: The issue here was that in some of the set-system-answers to the tutorial questions, the system did not allow flexibility for marking (the acceptance and evaluation of responses). There was no room for partial credit where questions required multiple steps and no provision for typing errors or alternative answers. The redesign idea was to re-format the system to appropriately deal with all possible solutions. However, more challenges emerged; for example, some students could not see all the questions, and some of the questions did not appear normal on the screen. It was discovered that this was a specific computer display setup problem and not an e-tutorial system issue.
- Challenges system use: This adaptation was made because novice computer users found it difficult to use the system. They experienced challenges such as filling in the blanks and correcting mistakes. The redesign idea was to add hints in Quizlet feedback, directing students to ask for assistance from the tutor. The objective was to help the tutor to identify and assist struggling students. However, some students found Quizlets confusing and could not figure out how to start Quizlet or do Quizlet again.:
- Resources: It was not easy for the students to access the resource and to search/find the information they needed to manage their task gap (section 6.3.5(2)).

The following section aimed to identify which issues still need work going into cycle 3.

6.3.11.3 Critical issues identified from cycle 2

1) Learning outcome

The issue here was performance was not good enough due to challenges such as lack of understanding of mathematics or student slip-ups. Therefore, there was a need to give students a chance to develop or refine their knowledge. This suggested that the focus of learning should be *developing or refining knowledge through adaptive rehearsing and exploring content* (formed by combining dimensions of learning from Task 1 and Task 2 (see section 5.2.3)).

2) Learning process alignment

The critical issue observed from the contradiction analysis (section 6.3.10.1(3) was a misalignment between the initial conceptualisation of the learning process model and the implementation results. Students' actions in Cycle 1 and Cycle2 suggested that most students preferred to do or try problems first and reviewed content to get answers when they experienced challenges. There was a need for change in the learning process model as a critical adaptation to deal with this contradiction.

Students' actions suggested that the approach should change from theory-first (read first, then do) to problem-first, read when required (do first, read when necessary). As a result, the following design changes were made in line with the problem-first approach.

3) Learning engagement

- Introduction: In Cycle2, the design of the introduction item was based on providing interactive media to provide engagement. However, the results suggested that interactive media alone was not enough to engage students. In line with the problem-first approach, providing a challenge based on the introduction could be helpful for students to engage effortfully and conceptually with the introduction content.
- Objectives: The issue was the pre-test and the KW questionnaire results did not match. Therefore, there was a need to decide which would work better under the problem-first approach.
- Resources: Making a challenge the core of the learning process required to start the students with the Quizlets but then use this to encourage them to engage with the reading. The issue was that it was difficult for the students to access the resources and search/find the information they needed to address their task gap. Results suggested a need to simplify the accessibility and search process of resources for the learners to more easily find the information they needed as they worked on the Quizlets or tutorial questions.

- Quizlets: Quizlets positively contributed to the e-tutorial as these motivated students to review the resources. However, some students found Quizlets confusing; they could not figure out how to start Quizlet or do Quizlet again. Results suggested a need to give students a chance to learn to use the Quizlet as part of the re-orientation of the learning process.

6.3.11.4 Summary of Critical issues: Cycle2

Table 6.21 shows a summary of issues identified (in the sections above) for consideration for re-design in the next cycle. Evidence from data on these issues and source(s) are also recorded in the table.

Table 6.21 Summary of Critical issues: Cycle2

Original design	Issues arising	Possible causes	
Conceptions/objectives	Contradictions	Evidence	Data source
Learning outcome			
1. Performance The target success rate was 80% per activity.	The performance objective of a success rate of 80% per activity was not achieved	A success rate of 80% was achieved in only 1 out of the 6 activities 2 of the remaining 5 had a reasonable performance with a success rate of 70%	LMS generated data
	This could have been due	such as:	Student work samples
	i) to student slip-ups.	spelling error	Activity 1
		not squaring	Activity 2
		using incorrect info	Activity 3
	ii) mathematical challenges	difficulty in solving simple equations with fractions	Activity 5
Learning orientation			
1. Learning process Initial conceptualisation of the learning process model: *read first, then do problems*	Student actions: do first read when required. Misalignment between the two.	Most students preferred to do problems first and reviewed content to get answers when they experienced challenges.	Contradiction analysis (section 6.3.10.1(3))
Learning engagement			
(Design Limitations)			
1. Introduction Make the Introduction interactive; make students spend more time reading the introduction.	No challenge for students to engage effortfully and conceptually with the introduction content.	Students spent a short time on the item; there were no follow-up actions to indicate whether the student had the correct idea of what they needed to do.	Observation Screen-capture
2. Objectives Introduce pre-test to assist students in identifying the knowledge gap	Pre-test and KW-questionnaire results do not match.	70% of the class scored less than 39%. 50% of students said they know the topic	Pre-test results KWL results

Original design	Issues arising	Possible causes	
Conceptions/objectives	Contradictions	Evidence	Data source
Learning outcome			
	Which one would work better under the problem-first approach?		
3 Resources Use Quizlet feedback, directing students to review resources and try again.	It was difficult for the students to i) access the resources,	The system presented a connectivity error.	Observation Screen capture
	ii) search/find the information they need to address their task-gap	The student needed assistance when playing the video to look for specific details in the video	Observation
		ii) Required format too constraining iii) No provision for typos iv) No provision for alternative answers	
4. Quizlets Use Quizlet feedback to direct students to ask for assistance from the tutor.	Quizlets were a positive contribution, But there were still issues to be addressed.	Quizlets, in some cases, motivated students to review the resources.	Observation
		Quizlets a little confusing; some students did not know how to start or could not figure out how to do Quizlet again.	Observation Interview
		LMS could not pick up students' responses in the Quizlets	LMS data

6.4 Summary

This chapter presented Cycle 1 and 2 results from in-class observations, interviews, questionnaires, screen capture videos, and system-generated data. For each modality, elements relating to students' engagement with the e-tutorial activities were discussed. Results suggested that student actions (how the students worked with the different components of the e-tutorial learning environment), student experience (students' reaction to the e-tutorial activities), system use (how students worked with the e-tutorial system) and tools of engagement (means used to enhance engagement) were the common elements of student engagement with the e-tutorial activities.

Results suggested the following student learning model: *Students prefer to do or try problems first and review content to get answers to experienced challenges*. This indicated a need to change the approach from a theory-first (construct knowledge by reviewing content first) to problem-first, making a challenge (introduced as Quizlets) the core of the learning process. Therefore, the critical focus for the development of Cycle3 was changing the learning model.

7 PHASE 3 RESULTS

7.1 Introduction

This chapter outlines and discusses the results relating to how students engaged with the e-tutorial activities in Cycle3 and Cycle4. It presents the results of the in-class observations, interviews, questionnaires, screen capture videos, and system-generated data. For each modality, the data collection process is briefly described, followed by a transcription of raw data of the results, presented as a data display matrix. This is followed by a brief discussion of individual elements that emerged from the results that gave specific insights into student engagement.

7.1.1 Review Process

The review process was aimed at transforming and improving the e-tutorial system. The evaluation of results in Cycle2 (see section 6.3.10) provided the reasons for change and development by identifying the issues to be addressed. This section describes the issues addressed, modifications made to the tutorial (by explaining what they are), justification of the change (in terms of how it is expected to overcome the issue) and objective for the change (in terms of what response it is expected to generate).

7.1.2 Overview of Tut 3

Cycle2 results formed the basis for reviewing, making decisions, and refining the system for Cycle3. This was based on a significant change identified at the end of the last chapter, changing the orientation from theory-first to problem-first. The product was Tut3, which addressed the issues identified at the end of Cycle2 (see Table 6.22) according to the change in orientation.

1) Learning outcome

A success rate of 80% in every activity was not achieved in Cycle2 since students consistently got wrong answers due to slip-ups such as spelling, not squaring, and using incorrect information. Results suggested a need to give students a second chance to review resources and correct these errors. The aim was to assist the students in developing and refining their knowledge through adaptive rehearsing and exploring content. To achieve this objective, the LMS conditional release function was used to lock progress until the pass mark was achieved.

2) Learning orientation

One of the critical issues identified in section 6.3.10.4 was a misalignment between the initial conceptualisation of the learning process model and the implementation results. The initial conceptualisation of the learning process model was to *read first, then solve problems;*

however, student actions suggested doing first read when required. Therefore, there was a need to change the conceptualisation of the learning process model to a problem-first approach: i.e., *do first*, *read when necessary.* To achieve this objective, the Quizlets were made the core of the learning process

3) Learning Engagement

Four design changes were made in the transformation to Tut 3, aimed at rectifying the four system design limitations that might have constrained the learning engagement process in Cycle2.

Introduction: The design of the introduction item was based on providing interactive media to provide engagement. The issue was that interactive media alone was not enough to engage students. In line with the problem-first approach, a need to provide a challenge based on the introduction was identified for students to engage effortfully and conceptually with the introduction content. To achieve this objective, the Introduction item was redesigned as a challenge by adding a test. The idea was to start the students with the test but then use this to encourage them to engage with reading the introduction content. Moreover, the test results would be a good indicator of students' engagement with the introduction content.

Objectives: In Cycle2, a pre-test was introduced, after which students identified knowledge gaps by filling in Know-Want to learn (KW) questionnaire. However, the pre-test and KW-questionnaire results did not match. In line with the problem-first approach, it was decided to drop the KKW questionnaire and keep the Pre-test, as it was performance-based.

Resources: The issue here was that it was not easy for the students to access the resources and to search/find the specific information they needed. Results suggested a need to make it easy to 1) open the resource and 2) simplify the search process for the students to find the information needed to address their task gap. To make it easy to open the resource, the resources were embedded into each LMS activity to enhance accessibility. And to simplify the search process, the details needed for the solution of the problem had to be accessible in the resource but not too much. This meant that students did not need to be given too much information (short); the resource must be based on one concept at a time (topical) and should not contain extra information (focused). Short flash videos made from PowerPoint presentations, broken into meaningful segments for which the learner can click on a button to go to the next segment, were used to achieve this objective. (see Appendix 2.2). However, the pdf notes were kept as one document to provide awareness of the scope of the topic.

Quizlets: The issue here was that some students found Quizlets confusing and could not figure out how to start Quizlet or do Quizlet again. Results suggested a need to give students a chance to learn to use Quizlet in keeping with the re-orientation of the learning process. To achieve this objective, students were given three opportunities to try the same Quizlet question, using elaborate feedback to direct them to relevant sections in resources.

Another issue was that the LMS could not pick up students' responses in the Quizlets, so the results were not stored. Results suggested a need for an alternative means of accessing Quizlets results. The option to set Quizlet to send results to the tutor's email was used to achieve this objective. The aim was to get data on students' responses to the Quizlets.

7.1.3 Summary Cycle 3 review process

Table 7.1 shows a summary review process of the critical issues that emerged from the results of Cycle 3.

Table 7.1: Summary Cycle 3 review process

Issue identified	Change made	Justification	Objective
(And how it was evident in the data)	Action	How it was expected to overcome the issue	What response was it expected to generate
Learning outcome			
1. Performance i) The target success rate was 80% per activity was not achieved,	Lock progress until the pass mark is achieved.	Make students review resources and try again.	Students achieve a Success rate of 80% in all activities.
ii) Wrong answers due to errors such as spelling, not squaring, using incorrect information	Add hints/examples at respective questions about the format	Enable students to correct errors	
Learning orientation			
Initial conceptualisation of the learning process model: *read first, then do problems* Student actions: do first read when required. Misalignment between the two.	Make the Quizlets (challenge) the core of the learning process.	Change in approach from *theory-first* to *problem-first.*	Students learn by adaptive rehearsing Quizlets problems and exploring content.
Learning engagement			
1. Introduction Students spent a very short time on the introduction.	Start the introduction with the test.	Encourage students to engage with reading the introduction content.	Students spend more time reading and achieve a reasonable level of success on the test.
2. Objectives Pre-test and KW-questionnaire results do not match.	Keep Pre-test and drop the KW questionnaire.	A pre-test is a better indicator of students' prior knowledge.	A low pre-test mark indicated a knowledge gap. Students see the need to do the e-tutorial.
3. Resources Resources not accessible due to connectivity error	Embed resources in LMS activity	Avoid external links	Make resources easy to open. and to simplify the search process.
and challenging to search/find specific information when needed	Create a short, topic-focused video	Student gets direct access to the relevant section in resources	

4. Quizlets i) Some students found Quizlets a little confusing	Give 3 chances to try Quizlet again.	Students learn to use Quizlet.	Students achieve a reasonable level of success.
ii) Quizlet feedback was not elaborate	Make feedback per Quizlet question elaborate.	A student who gets a wrong answer is direct to the relevant section in the resources.	Student review resources
iii) LMS could not pick up students' responses in the Quizlets	Set Quizlet to send results to the tutor's email	Make students' responses in the Quizlets accessible.	Get data on students' responses to the Quizlets.

7.2 Results Cycle3

This section presents the results of the in-class observations, interviews, questionnaires, screen capture videos, and system-generated data. For each modality, the data collection process is briefly described, followed by a summary of the results. This is followed by a brief discussion of factors that enabled or constrained engagement in the activities that emerged from this data modality.

7.2.1 Student Profile

In Cycle3, thirty-eight students completed the student profile questionnaire (see Appendix 12.1) out of a class of forty, of which 20 were male (52.6%) and 18 female (47.4%) students.

As in Cyles1 and 2, the student profile questionnaire responses still indicated gap year and computer literacy as two possible barriers to e-tutorial use.
Of these students, 19 (50%) were between 17 and 20 years old. Of the rest, 5 (13.2 %) were below 18 years, 9 (23.7%) were between 21 and 23 years, and 4 (10%) were 24 and over. Most of these students, 19 (50%) had completed their matric the previous year, 7 (18.4%) had one gap year, 6 (15.8 %) had two gap years, and 6(15.8 %) had more than two gap years. 11 (29%) of these students rated their computer experience as Novice/Beginner, Intermediate users were 24 (63%), and Expert users were 3 (8%).

Thirty-four (34) students of the 40 (85%) responded to the call to test the system. The students were asked to do a series of activities using the e-tutorial during the Mathematics tutorial period. They were given an orientation on how to log into the system, access the e-tutorial and access other resources they would have in the regular classroom environment (e.g., a scientific calculator). Also, the researcher, acting as a tutor, was available to assist the students.

7.2.2 Introduction Test

As shown in Table 7.1, the introduction item was redesigned to start the students with a test but then used this to encourage them to engage with the reading of the introduction content. The aim was to provoke students to read the introduction in order to comprehend where to go, what to do and how to do it. Students' performance in the introduction test is summarised in Table 7.2.

Table 7.2: Students' performance in the Introduction test

		Grade distribution			
Activity	No of attempts	< 60	%	>60	%
Introduction	34	21	62	13	38

Results indicate that adding a test to the Introduction item assisted in revealing the number of students who read the Introduction and the number that comprehended it. Table 7.2 suggests that many students, 21 out of 34 students or 62%, did not attain the benchmark score of 60% in the Introduction test.

7.2.3 Pre-test Attempts Statistics

In Cycle3, a Pre-test was given as a better indicator of students' prior knowledge as it is performance-based. Results are shown in the form of Attempts statistics in Figure 7.1.

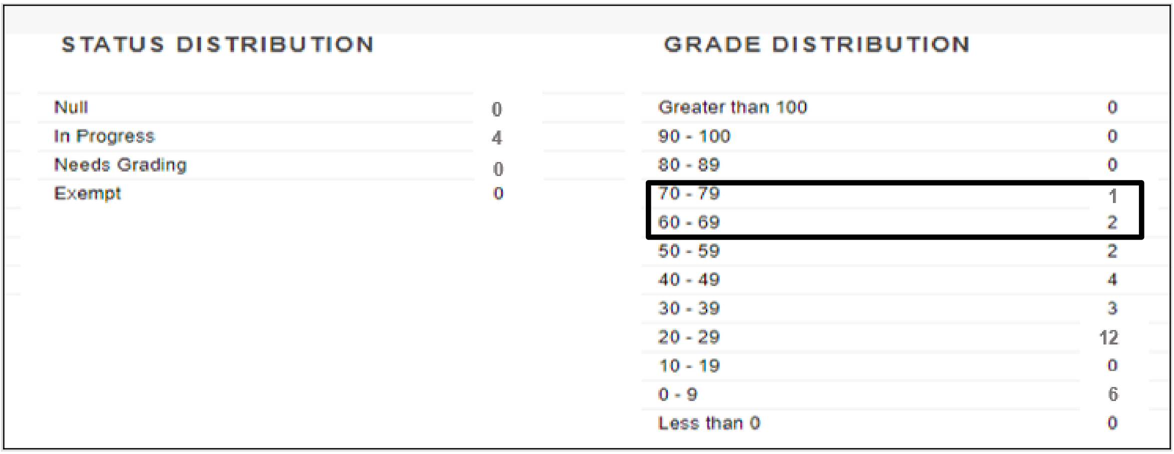


Figure 7.1: Cycle3 Pre-test attempts statistics

Results indicate that 30 attempts were made on the pre-test. However, only three managed to get a mark greater than 60%. Moreover, 21 (70%) scored between 0 and 39%. This indicated that most students did not know or needed to revise the topic. Results suggest that these students needed to learn basic trigonometry as covered by the e-tutorial system. The students would see this individually from the LMS performance feedback (see section 6.2.7.4), showing the mark obtained.

7.2.4 In-class Observation

As in Cycle 1 and Cycle2, the in-class observation focused on how students engaged with the e-tutorial activities and the challenges they encountered. The observation notes were collected through the researcher's encounters with students who asked for assistance when they experienced difficulties. Results are summarised in Table 7.3.

Table 7.3: Cycle 3 Observation data

Focus area	Observation
1. Student Engagement	1.1 S1, S2, S3, S4, S5, S6, S7 asked for assistance with Introduction, presented to the student on opening e-tutorial activities, (*students shown how to navigate presentation*) 1.2 S6, S7, S11, S12, S13, S14, and S15, used sketches and rough work to interpret and do Quizlet calculations. These students asked for assistance on how to input results into the system (*students were shown how to type answers in the system*) 1.3 Some students decided to work in groups (4 groups were identified); talking to each other, low voice levels. (*reason*, "we want to ace the activities") 1.4 S1, S15 requested assistance with accessing and reviewing resources. (S1 one was a novice computer user and S15 arrived late after the orientation session), (students were shown how to play the videos and scroll the pdf notes) 1.5 S1 explored resources before doing Quizlet questions; S15 explored resources after experiencing challenges answering Quizlet questions. 1.6 Ten (10) students asked for assistance with tutorial questions, used sketches and rough work to interpret and do tutorial questions then input results into the system. S4, S5, S6, S7, S11, S12, and S14 were disappointed with the results (marks) and wanted to know where they went wrong (*students were shown how to view the answers*). 1.7 Two students found looking at other websites
2. Challenges	2.1 S1, S9, S10 (*struggling students*) had difficulties moving forward. 2.2 these students exhibited signs of frustration when they repeated an activity 2.3 how to view the answers

In-class observations provided insight into the following four categories of engagement: 1) student actions, 2) system use, 3) student feelings, 4) social interaction and 5) system shortcomings.

1) Student actions

In-class observations suggest that students reviewed the Introduction presentation; however, some needed assistance on how to navigate the presentation (1.1).

Observations also indicate that students used sketches and rough work to interpret and work out the Quizlet questions on paper before completing activities online (1.2). These student actions suggested that students used rough work to recall knowledge and get an idea of how to complete the activity. In other words, they used paper and pen (as tools) to help them do the work (i.e., solve the problem).

At the same time, students accessed the resources, but some students (e.g., novice computer users) struggled with playing videos and scrolling down pdf notes; others (e.g., one who missed orientation) were not aware of the purpose of these resources (1.4). Observations also indicate that some students were able to use these resources to answer Quizlets questions (1.4, 1.5). While one student (S1) explored content resources before doing Quizlet questions, another one (S15) explored content resources after experiencing challenges answering Quizlet questions (1.5). The student actions suggested that these students were motivated/provoked to review content when they tried to answer Quizlet questions and to try again if they got a question wrong. However, there was a need to limit the number of attempts to enhance progress.

2) System use

Observation results suggested that some of the students worked out the Quizlet questions (1.2), reviewed resources (1.2, 1.4, 1.5), and worked out the tutorial questions (1.6). However, the students faced several challenges while using the system, such as navigating presentations, playing videos and scrolling pdf notes, and viewing the answers (2.1; 2.2; 2.3).

3) Student feelings.

Some students felt disappointed with the results as they worked on the system (1.6; 2.2). The results suggested that such students needed to be identified and supported by the tutor.

4) Social interaction

Observations also identified four groups of students who worked together through discussions of the activities (1.3). This observation suggested that the social interaction provided them with support when needed.

5) System shortcomings

Quizlet questions were not straightforward, some answers seemed incorrect, and Quizlet feedback (directing students to review resources and try again) was not sufficiently clear and detailed. Moreover, the set-system-answers to some tutorial questions had flaws; for example, the rounding precision chosen by the student may not have been the level of precision used for marking.

7.2.5 Screen-capture Data

In Cycle3, no students used the screen capture software.

7.2.6 Interview Responses

Interviews were recorded and later transcribed. These interviews were semi-structured, comprising predetermined questions on the students' teaching and learning needs, their challenges, and their perceptions, attitudes and experiences in the current teaching and learning situation.

Table 7.4 shows extracts for the interview transcript in Appendix 4.3. Responses to the question "How did you go about doing the activity?" were chosen for the first focus area. and organized according to the results attained by the students (competent 60% < X, borderline 50% ≤ X ≤59% and at-risk (weak): X < 50%; see section 5.2.1(3)). The aim was to see whether there were any differences among the groups. Under the second focus area, responses to the question "What challenges did you encounter" were chosen.

Table 7.4: Summary of Interview responses.

Focus area	Observation
1. Student Engagement Process	(How did you go about doing the activity?) (competent) 1.1 S5 "Work out the sum, calculate it twice to make sure it is correct, Do not panic when I see that it is tough, be patient", 1.2 S5 "If I (*do*) not understand, I ask" (*who?*) "tutor or peer who explain what it says" 1.3 (*if you experience a problem, do refer to resources?*) "I do look at them, because sometimes you may think that you know, but not" 1.4 S7 "Start with the Quiz; if stuck, I go to examples and try to remind myself." (borderline) 1.5 S6 "I start here (*resource*), then Quiz, then test. Take exam pad and calculate, then write the answer in computer." (weak) 1.6 S4"I was assisted by the student sitting next to me. Do roughly, on the side, then input into the computer". 1.7 (*If the answer is wrong?*) "that is when I start to ask someone to assist me". 1.8 (*so you do not look here (resources*) "I did not think about looking at examples until you (*tutor*) showed me examples, there was improvement."
2. Challenges	(What challenges did you encounter?) (System) 2.1 S3 "…nervous because first time to use computer." (Test) 2.2 S5 "... some questions seem to have something that you missed out." 2.3 S1 "I solve the problem, but it is difficult to punch in the computer." 2.4 S1 "Only 2, 1 and 2 done. Not able to finish, so had to redo it again." 2.5 S6 "Do not know how to put steps; Steps are different from the way done in high school." (Resources) 2.6 S3 "Problematic at first because of no basics of trig. Now I read notes and understand. Forwarding the video, ok." (Quiz) 2.7 S2 "sometimes do not read feedback; just click try again." 2.8 S3 "quiz in activity 3 was problematic, tried several times but failed"

Interview responses provided insight into the following four categories of engagement: 1) student actions, 2) student feelings, 3) social interaction and 4) system use.

1) Student actions

Interview responses suggested that students worked on paper and then entered answers on the computer (1.1, 1.5, 1.6). In addition, two student approaches to reviewing content resources were observed; students either explored resources before doing Quizlets or when they experienced challenges answering Quizlets (1.3, 1.4, 1.8).

2) Student feelings

Novice computer users felt nervous because it was their first time using a computer (2.1, 2.3). They thought that they could solve the problems, but it was difficult to punch the answers into the computer because, for example, the steps were not the same (2.6).

3) Student social interaction

Interview responses indicate these students asked for assistance from peers and tutors (1.2, 1.6, 1.7, 1.8) when students experienced technical or academic challenges. This suggested that social interaction (student-student and student-tutor) provided them with much-needed support.

4) System use

Interview responses suggested that four interviewees worked out the Quizlet questions (1.2) and reviewed resources (1.4, 1.5, 1.8) without any problems. However, the students faced several challenges while using the system, such as feeling nervous because it was their first time using a computer (2.1), finding it difficult to punch answers into the computer (2.2) and a few questions that seemed to have something missed out (2.3).

7.2.7 Journal Responses

As in the previous Cycles, all students were encouraged to complete a learning journal (Section 4.2.1) detailing their experiences during the tutorial. In Cylce3, the tutor clearly explained the purpose of the learning journal (i.e., to collect students' reflections about their personal experiences using the e-tutorial) when the e-tutorial was introduced to the students. This resulted in an average response rate of 65%. Additionally, questions were asked to investigate those emotional attributes that contributed to the students' affective engagement.

- Questions on attitude inquired about *w*hat part(s) (tests, quizzes, videos, or pdf notes) of the Activity the student found interesting, challenging or frustrating.
- Questions on feeling inquired about how the student felt as they were doing the Activity, whether calm, relaxed nervous, or tense.

- Questions on confidence inquired whether they did the activities on their own, or were assisted by a tutor or peers, and then *w*hich question of the Test the student managed to do with peers' help.
- Questions on satisfaction inquired about how well the student understood the work covered in this activity. The options were: understood the topic well (got 74-100%) or poorly (got 30% or below)).
- Questions on Quiz feedback inquired about the suitability of the QUIZ feedback information. The options were: informative, easy to follow, not clear, directed me where to study in resources, was useless.

Each question was followed by a long answer space where students could give reasons for their choice.

A summary analysis of Cycle3 Journal responses (see Appendix 8.3) suggested three types of engagement: 1) students' feelings, 2) system use challenges, and 3) social interaction.

1) Students' feelings

Journal responses indicate that, on average, students found the Quizlets (average response was 48%) and the Test (average response was 50%) more interesting than watching the Video (average response was 9%) or reading Notes (average response was 11%). The students felt that the "Test was interesting because it was more challenging it also need concentration and focus". The Quizlets (on the other hand) "had simple questions and was understandable" and "it prepared *them* for what was to come in the test". This suggested that students were more interested in doing calculations. In addition, results suggested that the majority (more than 75%) of the students felt that the e-tutorial was interesting, easy to work with and understood the topic well. However, some students (20%) felt uncomfortable using the system (2.9).

2) System use

An average of 48% of students did not find any challenges in using the system (2.5). A very small number of students experienced difficulties with resources, 1% for notes and 2% for video (2.8; 2.9).

3) Social interaction

A small number of (4-7%) students who experienced challenges with using the system received assistance from tutor or peers (3.2, 3.3).

7.2.8 LMS Generated Data

In Cycle3, the improvements in the e-tutorial made it possible to extract the full range of data types (section 4.2.4) from the grade centre of the LMS. The following data sets were extracted from the grade centre of the LMS; 1) Students' work samples, 2) Item analysis, 3) Column statistics, 4) Attempts statistics, and 5) View all attempts.

7.2.8.1 Student work samples

Students' work samples showed the same types of students' errors as identified in Cycle2 (section 6.3.6(1)). That is spelling, not squaring, rounding, solving simple equations, and using incorrect information. These are summarised in Table 7.5 below.

Table 7.5: Student Error Analysis

Error	Number of cases
Spelling (activity 1),	11 (out of 40 attempts)
Spelling (activity 4),	11 (out of 28 attempts)
Not squaring, rounding (activity 2),	9 (out of 37 attempts)
Solving simple equations (activity 3),	5 (out of 32 attempts)
Using incorrect information (activity 3, 4, 5).	5 (out of 24 attempts)

These results suggested that these errors could have affected students' performance.

7.2.8.2 Item Analysis

Cycle3 item analysis aimed to reassess the quality of the Activities items and to see whether there was a need to improve the questions. Table 7.6 shows a summary of Cycle3 item analysis.

Table 7.6: Summary of Cycle3 Item Analysis

Activity	Attempts status		Average performance		Questions	
	Completed	In Progress	Time	Score	Discrimination	Difficulty
Activity1	38	3	01hr32min	79%	5 good	2 easy 3 medium
Activity2	35	2	02hr02min	79%	6 good	5 easy 1 medium
Activity3	32	0	02hr25min	84%	3 good 1 fair	1 easy 3 medium
Activity4	26	2	00hr52min	82%	4 good	2 easy 2 medium
Activity5	22	3	00hr50min	79%	5 good	2 easy 3 medium
TOTAL	153	10				
AVERAGE	30,6	2		80,6%		

Table 7.7 provided insight into the following three categories of engagement: 1) attempts status, 2) students' performance and 3) question quality.

1) Attempts status

Table 7.7 shows that out of 153 attempts, only 10 (7%) students did not submit their answers, recorded by the system as an *attempt in progress*. This result was below the 18% recorded in Cycle2 and was within acceptable levels/limits.

2) Students' performance

Students' performance was good since the average score in each activity was above the targeted 60%. This result was within acceptable levels of performance.

3) Questions Quality

Table 7.7 indicates that there were no questions in all Activities that could be poor discriminators of student performance. Moreover, no hard questions were identified by the system. This result suggested that more students were answering tutorial questions correctly. This supported observation made in section 2) above and implied that the e-tutorial was starting to work well.

7.2.8.3 Column statistics

Column Statistics displayed statistics for an Activity, represented by a grade centre column, showing how students fared on each Activity and how the grades were distributed. The aim was to see activities where the targeted pass rate was achieved.

Table 7.7 below shows a summary of Column Statistics (section 4.2.4) in Cycle3, indicating how the grades were distributed.

Table 7.7: Summary of Cycle3 grade distribution

Activity	Number of students who did an activity	Grade distribution		
		< 60%	>60%	Success rate %
Activity 1	38	7	32	85
Activity 2	35	4	31	89
Activity 3	32	6	26	81
Activity 4	26	3	25	89
Activity 5	22	1	23	96
	AVERAGE 30,6			AVERAGE 88

Results in Table 7.7 indicates that more than 80% of students attained 60% or more in each activity. In other words, in all activities, a success rate of more than 80% was achieved by those who completed the activity. However, the number of students who completed the tutorial reduced from 38 in Activity 1 to 22 in Activity 5 at an average dropout rate of 4 students per activity. This indicated a need to encourage students to complete all the activities.

7.2.8.4 Attempts statistics

In Cycle3, attempts statistics were extended to include the attempt count of correct answers (as %) per section/step of each activity question, as shown in Figure 7.1 below.

Variable Identifier/Correct Answers		Attempt Count		Attempt Count as Percentage of Total
a		28		87.5%
Evaluation Method	Correct Answer		Case Sensitivity	
Exact Match	AC			
Variable Identifier/Correct Answers		Attempt Count		Attempt Count as Percentage of Total
b		21		65.625%
Evaluation Method	Correct Answer		Case Sensitivity	
Exact Match	117			
Variable Identifier/Correct Answers		Attempt Count		Attempt Count as Percentage of Total
c		20		62.5%
Evaluation Method	Correct Answer		Case Sensitivity	
Exact Match	sin70			
Variable Identifier/Correct Answers		Attempt Count		Attempt Count as Percentage of Total
d		25		78.125%
Evaluation Method	Correct Answer		Case Sensitivity	
Exact Match	109.9			

Figure 7.2: Example of attempt count of correct answers: Activity 3, question1

The aim was to determine the overall quality of an Activity in terms of the quality of the individual questions and which sections were unclear or were misinterpreted. A summary of attempts statistics presented is in Table 7.8.

Table 7.8: Activity-attempts statistics

(Question type fmb = fill multiple blanks and ma =multiple answer)

Activity	Question	Correct answers (%)	Partially correct answers (%)	Not answered (%)	% of correct answers per section/step of each question in each activity (rounded to nearest whole number)										
					a	b	c	d	e	f	g	h	i	j	k
1	1 fmb	70	17.5	5	80	75	80								
	2 fmb	77.5	12.5	7.5	80	80	88								
	3 fmb	57.5	25	7.5	78	70	75	68							
	4 fmb	45	22.5	12.5	53	63	55								
2	1 ma				84	92	89								
	2 ma				81	89	92								
	3 ma				89	92	84								
	4 fmb	0	100	0	97	95	97	81	5	84	0	0	95	0	95
	5 fmb	38	62	0	97	95	100	100	92	92	97	38			
3	1 fmb	44	50	3	88	66	63	78							
	2 fmb	0	100	0	6	93	88	63	0						
	3 fmb	13	84	0	75	72	44	66	81	88	59	53	59		
4	1 fmb	57	39	0	93	71	82								
	2 fmb	28	71	0	89	82	85	82	60	68					
	3 fmb	0	100	0	85	82	89	85	57	0					
5	1 fmb	42	58	0	79	83	83	75	91	58					
	2 fmb	0	100	0	92	0	100	67	92	45					
	3 fmb	0	100		96	0	0	62	83	63					
	4 fmb	58	42	0	100	96	92	71	83	67					

Design Error Analysis Key:

>80	Acceptable	
60-79	System answer error-tolerance	e.g., spelling, syntax
< 60	System answer contains minor errors	e.g., evaluation method; "exact" Vs "contains."
0	The system answer contains a significant error	e.g., wrong

Table 7.9 indicates significant system answer errors, resulting in 0% correct answers in activity steps/sections. These errors occurred in Activity 2 (3 were identified), Activity 3 (1 was identified), Activity 4 (1 was identified) and Activity 5 (3 were identified). However, these were not severe since the system allowed correcting the answers and remarking students' answers already in the system. Results indicated improvements in all the questions, as shown in the green rows in Table 7.9.

Table 7.9: Improvements in Activity-attempts statistics

Activity	Question	Correct answers (%)	Partially correct answers (%)	Not answered (%)	Average grade per section/step of each activity (% correct answers)										
					a	b	c	d	e	f	G	h	i	j	k
2	4 fmb	0	100	0	97	95	97	81	5	84	0	0	95	0	95
		70	30						89	86	92	95	97	97	97
3	2 fmb	0	100	0	6	93	88	63	0						
		41	59		81				59						
	3 fmb	13	84	0	75	72	44	66	81	88	59	53	59		
		31	69		91	88	81	78							
4	3 fmb	0	100	0	85	82	89	85	57	0					
		29	71		89	89	89		??	71					
5	2 fmb	0	100	0	92	0	100	67	92	45					
		42	58			83									
	3 fmb	0	100		96	0	0	62	83	63					
		46	54			96	96	66							

Key:

Results after system error correction			

7.2.8.5 View all attempts

In Cycle3, students were allowed to review content and try again. This resulted in the system recording multiple grades for the same activity. The Attempts tab listed all submitted attempts, each attempt's grade, submission date, status, and duration, as shown in Figure 7.2 below.

Username	Grade	Attempt Number	Date	Status	Duration
216101247	12	1	March 4, 2016 3:10:44 PM	Completed	00:16:36
216101247	0	2	March 11, 2016 2:02:05 PM	In Progress	
216101247	17	3	March 9, 2016 9:54:50 AM	Completed	01:10:57
216101247	19	4	March 11, 2016 1:57:44 PM	Completed	00:16:45
216133513	17	1	March 8, 2016 10:05:39 AM	Completed	01:10:46
216036402	19	1	March 8, 2016 10:17:31 AM	Completed	01:25:34
216056950	15	1	March 4, 2016 3:32:04 PM	Completed	00:13:27
216140927	21	1	March 8, 2016 9:36:33 AM	Completed	00:16:37
216038510	15	1	March 4, 2016 3:08:38 PM	Completed	79:00:43
216241243	13	1	March 4, 2016 3:03:23 PM	Completed	00:26:09
216241243	23	2	March 9, 2016 8:56:54 AM	Completed	00:22:30
216068894	11	1	March 4, 2016 3:23:13 PM	Completed	01:30:55
216068894	23	2	March 9, 2016 8:47:46 AM	Completed	00:16:58
216032393	2	1	March 5, 2016 3:54:27 PM	Completed	
216032393	21	2	March 9, 2016 8:59:27 AM	Completed	00:23:10
215020316	0	1	March 14, 2016 10:19:07 AM	In Progress	
216032474	12	1	March 4, 2016 3:03:10 PM	Completed	00:51:23
216032474	11	2	February 29, 2016 3:17:38 PM	Completed	00:21:32
216032474	18	3	March 9, 2016 9:37:25 AM	Completed	00:33:20
216113830	9	1	March 4, 2016 3:02:26 PM	Completed	01:01:24
216113830	22	2	March 9, 2016 9:27:42 AM	Completed	00:14:38
216140781	7	1	March 16, 2016 8:27:55 AM	Completed	00:15:24
216140781	5	2	March 4, 2016 3:30:18 PM	Completed	01:13:43
216140781	15	3	March 14, 2016 10:22:57 AM	Completed	00:14:57
216140781	6	4	March 9, 2016 10:01:31 AM	Completed	00:14:17

Figure 7.3: An example list of all submitted attempts: Activity 1

From the view of all attempts, attempts were grouped and counted for each activity. Table 7.10 shows a summary of the number of attempts per activity and the number of attempts in which grades improved, dropped, or remained the same.

Table 7.10: Summary of the number of attempts per activity.

Activity	Attempt 1	Attempt 2	Attempt 3	Attempt 4	Improved (between first and last attempts)	Dropped	No change
Activity 1	38	19	18	4	15	3	1
Activity 2	35	26	11	4	22	2	2
Activity 3	32	5	1	0	6	2	0
Activity 4	26	9	3	0	8	1	0
Activity 5	22	5	3	0	5	0	0
TOTAL					56	8	3

Results indicate that some students attempted the activities up to four times. In the majority (56 out of 67) of these cases, students' performance improved between the first and last attempts. The results suggested that these students may have benefitted from the chance to try again. However, there were a few instances where the grades dropped or remained the same.

7.2.8.6 System responses

In Cycle3, the focus was on the changes in the system responses which resulted from the introduction of Quizlets; 1) Quizlet feedback and 2) Quizlets results.

1) Quizlet feedback

Figure 7.2 shows how feedback per Quizlet question was made elaborate, where a student who gets a wrong answer is direct to the relevant section in resources.

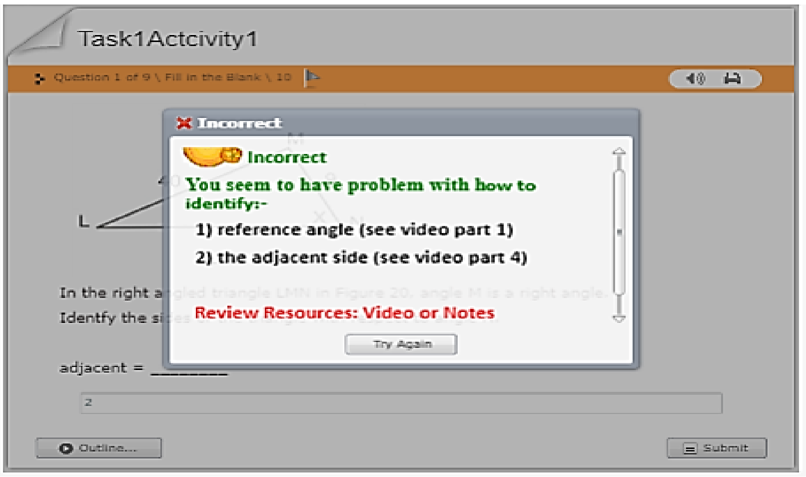


Figure 7.4: Elaborate feedback per Quizlet question

2) Quizlet results

In Cycle2, it was observed that the LMS could not pick up students' responses in the Quizlets, so no data was available. In Cycle3, this issue was addressed when the option to set Quizlet to send results to tutors' email was used. Quizlets results were captured (Appendix 10.1) and were summarised in Table 7.11.

Table 7.11: Summary of Quizlet results

Activity	No of attempts	Quizlet Responses	No of Passes	No of Fails	Time Range
1	38	46	24	22	3.28 – 49.38
2	35	26	26	0	0.14 – 23.34
3	32	8	7	3	1.07 – 25.07
4	26	9	8	2	2.05 – 30.16
5	22	11	11	0	3.01 – 1hr 11.55

Summary of Quizlets results in Table 7.11 indicated that of the 38 students who did Activity1, only 24 (60%) managed to pass. Six of those who failed tried again. However, the number of Quizlets responses declined in activities 2, 3, 4 and 5. The Student Quizlet performance results suggested that some of the students were struggling with answering the Quizlets questions despite the elaborate feedback per question. These students needed to be identified and assisted.

7.2.9 Summary of Key Results

Level-one analysis of regularly occurring insights into student engagement identified the following local themes:

1) Learning outcomes: students' performance, students' errors.

2) Student actions: student reading, student strategy, social interaction.

3) Student experiences: frustrations, satisfactions.

4) System use: system affordances, problems in using the system, system shortcomings.

1) Learning Outcomes: students' performance, students' errors

- Results indicate that an average success rate of 88% was attained in Cycle3 (section 7.2.8.3). And the average score in each activity was 80,6% (+above the targeted 60%).
- Students' work samples showed the same types of errors as identified in Cycle2. That is spelling, not squaring, rounding, solving simple equations, and using incorrect information (section 7.2.8.1).

2) Student actions: student reading, student strategy, social interaction.

- Student reading: some students were able to use the resources to answer Quizlets questions. Two student approaches to reviewing content resources were observed; students either explored resources before doing Quizlets or when they experienced challenges answering Quizlets. (sections 7.2.4(1); 7.2.6(3)).

- Rough work strategy: observations and interview responses suggested that students worked on paper before entering answers into the system (sections 7.2.4(1); 7.2.6(1)).

- Support from peers: when students experienced technical or academic challenges, they asked for help from peers (sections 7.2.4(1); 7.2.6(1)). Observations also identified four groups of students who worked together (sections 7.2.4(4)).

3) Student experiences: frustrations, satisfactions.

- Frustrations: some students felt disappointed with the results as they worked on the system (section 7.2.4(3)). Novice computer users felt nervous because it was their first time using a computer (section 7.2.6(2)).
- Satisfactions: more than 75% of the students felt that the e-tutorial was interesting and easy to work with (section 7.2.7(1)).

4) System use: system affordances, problems in using the system, system shortcomings

- System affordances: Results suggested that the students worked out the Quizlet questions (section 7.2.8.6(2)), reviewed resources (section 7.2.6(1)) and worked out the tutorial questions (section 7.2.8.3).

- Problems in using the system: An average of 48% of students did not find any challenges in using the system (section 7.2.7(4)). A very small number of students experienced difficulties with resources, 1% struggled with scrolling down pdf notes (section 7.2.7(4,)), and 2% struggled with playing videos (section 7.2.7(4)). Novice computer users faced several challenges while using the system, such as feeling nervous because it was their first time using a computer and finding it difficult to punch answers into the computer (section 7.2.7(4)). (7.2.6(4)).

- System shortcomings:
    - Quizlet questions were not clear; some answers seemed to be incorrect.
    - Quizlet feedback (directing students to review resources and try again) was not sufficiently clear and detailed.
    - Moreover, the set-system-answers to some tutorial questions had flaws; for example, the rounding precision chosen by the student may not have been the level of precision used for marking.

7.2.10 Evaluation of Results

As discussed in Chapter 6, the evaluation informed the decision process by providing an interim data analysis. The evaluation process involved 1) contradiction analysis of components of the e-tutorial activity system and learning environment, 2) evaluation of the effectiveness of Cycle3 changes, and 3) identification of the critical issues to work on Cycle4.

7.2.10.1 Contradictions analysis

In the analysis of components of the e-tutorial activity system, contradictions were found within three components of the e-tutorial activity system. These were mainly primary contradictions found within three components of the e-tutorial activity system, i.e., object, subject, and tool.

1) Object

As explained in section 5.2.1(3), the performance objective of the e-tutorial was to achieve a success rate of 80% per activity. Results (see Table 7.8) indicated that the 80% performance objective was achieved. However, contradictions occurred within the element *object* when the number of students who completed the tutorial reduced from 38 in Activity 1 to 22 in Activity 5 at an average dropout rate of 4 students per activity. This indicated a need to encourage students to complete all the activities.

2) Subject

By design, students were required to correctly complete the tutorial activities (to improve trigonometry knowledge and skills) using the e-tutorial. However, contradictions occurred within the element *subject,* where some students were still getting wrong answers due to errors such as spelling, not squaring and using incorrect information. As well as mathematical challenges not directly related to trigonometry, such as solving simple equations with fractions (section 7.2.8.1).

3) Tool

In Cycle2, Quizlets were introduced as challenges and rehearsal problems to assist students in developing and refining their knowledge. However, observation and student responses revealed contradictions within the element *tool* in the form of system shortcomings.

- Some Quizlet questions were unclear, some answers seemed incorrect, and Quizlet feedback (directing students to review resources and try again) was not sufficiently clear and detailed (section 7.2.4(6)).

- Several flaws were found in the set-system-answers, resulting in 0% success rates in the activity steps/sections (section 7.2.7.4).

Results suggested a need for correcting these errors.

7.2.10.2 Evaluations of Cycle3 changes

In the Cycle3 evaluation, the result of each change made during the review process was assessed by contradiction analysis in relation to achieving objectives set during the review process and overcoming the issue.

1) Learning outcome

This section evaluated the effect of implementing the LMS conditional release function, which was used to lock progress until the pass mark was achieved. Students' work samples indicated that students made the same types of errors as identified in Cycle2 (section 7.2.8.1). However, in Cycle3, progress was locked (through conditional release) until the pass mark was achieved. Some students attempted tests up to four times (section 7.2.8.5). In 17 cases, performance improved in each attempt. As a result, the average score per activity was 80,6% (section 7.2.8.2), and an average success rate of 88% was attained (section 7.2.8.3). The results suggested that these students may have benefitted from the chance to try again. This indicated that combining conditional release with the chance to repeat/try again enabled students to think about what they were doing/not doing, rectify their errors and encouraged struggling students to improve their performance.

2) Learning orientation

This section evaluates the change in the conceptualisation of the learning process model to the problem-first approach. The idea was to make Quizlets (challenge) the core of the learning process. Results suggested that students either explored resources before doing Quizlets or when they experienced difficulties answering Quizlets (sections 7.2.4(1); 7.2.6(3)).

3) Learning Engagement

This section evaluates the design changes made in Cycle3, aimed at rectifying the system design limitations that might have constrained the learning engagement process in Cycle2.

Introduction

The issue was that students spent a very short time on the item despite being interactive. And the tutor could not tell whether the student had read the Introduction. Results suggested a need to include follow-up actions to indicate whether the student has the right idea of what they need to do. To achieve this objective, the Introduction item was redesigned as a challenge by adding a test. The idea was to make students spend more time on the Introduction, reading for the test. Moreover, the test results would indicate whether the student has the right idea of what they need to do.

Results (section 7.2.2) indicated that adding the test to the introduction assisted in revealing the number of students who read the introduction and the number that comprehended it. However, students did not engage effortfully and conceptually with the introduction content since a large number (62%) of students did not attain the benchmark score of 60% in the introduction test. This suggested a need to encourage students to improve their performance by paying attention when reading for the test.

Objectives

In Cycle2, a pre-test was introduced, after which students identified knowledge gaps by filling in Know-Want to learn (KW) questionnaire. However, the pre-test and KW-questionnaire results did not match. It was decided to drop the KW-questionnaire and keep the Pre-test. The pre-test was a better indicator of students' prior knowledge since it was performance-based. The students would see this individually from the LMS performance feedback showing mark obtained. Cycle3 pre-test results suggested that the pre-test was a reasonably precise indicator of students' prior knowledge, showing that most students (70%) scored between 0 and 39%. These students needed to learn or revise the basic trigonometry covered by the e-tutorial system.

Quizlets

The issue was that some students found Quizlets confusing; students could not figure out how to start Quizlet or do Quizlet again. Moreover, Quizlet feedback was not elaborate enough. Results suggested a need to give students a chance to learn to use Quizlet. To achieve this objective, students were given three opportunities to try the same Quizlet question, using elaborate feedback to direct them to relevant sections in resources.

The summary of Quizlets results indicated that Quizlets positively contributed to student engagement (section 6.3.10.4(3)). However, there were still issues to be addressed. First, the number of Quizlets responses declined in activities 3, 4 and 5 (section 7.2.7.6(2). Although a majority (63%) of students felt that Quizlet feedback was easy to follow (section 7.2.7(3.6)), in some cases, students did not pay attention to the feedback (section 7.2.6(2.7)). Moreover, only a small number (30%) found feedback informative and or directed them where to study in resources (10%) (section 7.2.7(3.7; 3.8)). Results suggested that some students were still struggling to answer Quizlets. These needed to be identified and assisted.

Resources

The issue was that it was not easy for the students to access the resources and search/find the specific information they needed. Results suggested a need to make it easy to 1) open the resource and 2) simplify the search process for the learners so that they can more simply find the information they needed to address their task gap. To make it easy to open the resource, the resources were embedded into each LMS activity to enhance accessibility. Resources were changed to short, topical, and focused videos to make it easy for students to access and review content. Results suggested that a minimal number of students experienced challenges with resources (section 7.2.7(2)).

5) Summary of issues resolved in Cycle3

Cycle3 evaluation showed success in the four changes made during the review process in terms of achieving objectives set during the review process and overcoming the issue. Success was achieved in the 1) objectives, 2) performance, 3) Quizlets, and 4) resources. Table 7.12 shows a summary of the four issues which were resolved.

Table 7.12: Summary of issues resolved in Cycle 3

Issues arising	Redesign	Results	
	Action	Effect	Evidence
Learning outcome			
Performance			LMS data

Issues arising	Redesign	Results	
	Action	Effect	Evidence
The target success rate of 80% per activity was not achieved,	Lock progress until the pass mark is achieved.	Success rate greater than 80%. Students can correctly complete activities. Number of repeat attempts per activity	Column statistics Item Analysis View all attempts
Learning orientation			
Misalignment between the Initial conceptualisation of the learning process model: *read first, then do problems* and student actions: *do first read when required*.	Change the learning process model from *theory-first* to *problem-first* .	Make the Quizlets (challenge) the core of the learning process.	Students explored resources before doing Quizlets or when they experienced difficulties answering Quizlets.
Learning engagement			
1. Objectives pre-test and KW-questionnaire results did not match	Drop KW-questionnaire and keep the Pre-test	The pre-test was a reasonably precise indicator of students' prior knowledge.	Pre-test results
2. Quizlet results No data from students' responses in the Quizlets.	Set Quizlets to send results to email	Quizlet results were available.	Captured in Appendix 10.
3. Resources Resources not easy to: access search	Embed resource in LMS Activity Create a short topic-focused video.	A small number of students experienced challenges with resources.	Interview and Journal responses

7.2.10.4 Summary of Critical issues in Cycle 3

Table 7.13. shows a summary of two remaining critical issues identified in Cycle 3 and the corresponding proposed pedagogical and technological solutions.

Table 7.13: Summary of Critical issues in Cycle 3

Redesign	Issues arising	Possible causes	
Changes/objectives	Contradictions	Evidence	Data source
Learning engagement			
1. Introduction Redesigned Introduction as a challenge by adding a test.	Students did not engage effortfully/conceptually with the introduction content.	62% of the students did not attain 60% in the introduction test	Introduction test results
2. Quizlet Give students three chances to try the same Quizlet question, using elaborate feedback to direct them to relevant sections in the resources.	Some students were still struggling with answering the Quizlets. These needed to be identified and assisted.	There were still issues to be addressed: i) the number of Quizlets responses declined in activities 3, 4 and 5. ii) students ignored the feedback.	Quizlets results

Redesign	Issues arising	Possible causes	
Changes/objectives	Contradictions	Evidence	Data source
Learning engagement			
		iii) only 30% found feedback informative and or directed.	

7.3 Results Cycle 4

Cycle 4 results present the data from the in-class observations, interviews, questionnaires, screen capture videos, and system-generated data. For each modality, the data collection process is briefly described, followed by a summary of the results. This is followed by a brief discussion of factors that enabled or constrained engagement in the activities that emerged from this data modality.

7.3.1 Review Process

Having identified the weaknesses/issues of the e-tutorial system in Cycle 3 that needed to be addressed (summarised in Table 7.13), this review provided the direction for the transformation and improvement of the e-tutorial system.

7.3.1.1 Overview of Tut4

In Tut 4, two changes were made to rectify the two outstanding issues identified in Cycle 3.

1) Introduction

The issue was poor performance in the introduction test, which suggested that students did not pay attention to what they were reading. Results suggested a need to encourage students to improve their performance by paying attention when reading for the test. The adaptive release condition was also implemented in the Introduction test to achieve this objective. The idea was to allow the students to repeat the test until the release condition was met.

2) Quizlets

The issue was that some of the students were still struggling with answering the Quizlets. These students needed to be identified and helped. To achieve this objective, Quizlet feedback was set to tell the student to ask for assistance after failing three attempts. The aim was to encourage struggling students to come forward for help.

7.3.1.2 Summary Cycle 4 review process

Table 7.14 shows a summary review process of the critical issues that emerged from the results of Cycle 4.

Table 7.14: Summary Cycle 4 review process

Issue	Change made	Justification	Objective
(And how it was evident in the data)	Action	How it is expected to overcome the issue	What response is it expected to generate
1. Introduction Poor performance in the Introduction test	Add adaptive release	Make reading the Introduction compulsory.	Students spend more time reading.
2. Quizlets Some of the students still needed help with answering the Quizlets.	Set Quizlet feedback to tell the student to ask for help after failing three attempts.	Identify struggling students	Assist struggling students

7.3.2 Student Profile

In Cycle 4, the student profile questionnaire (see Appendix 12.1), completed by thirty-six students of a class of forty, indicated 30 male (83.3%) and 6 female (16.7%) students. Most of these, 18 students (50%), were between 18 and 20 years old. Of the rest, 6 (16.7 %) were below 18 years, and 12 (33.3%) were between 21 and 23 years. Most of these students, 24 (66.7%), had completed their matric the previous year, 8 (22.2%) had one gap year, 1 (2.8 %) had two gap years, and 3(8.3 %) had more than two gap years. A large number, 17 (47.8%), of these students rated their computer experience as Novice/Beginner, while Intermediate users were 4 (38.9%), and Expert users were 5 (13,9%). As in Cycles 1, 2 and 3, student profile questionnaire responses still indicated gap year and computer literacy as two possible barriers to e-tutorial use.

Thirty-six (36) students of the 40 (90%) responded to the call to test the system. The students were asked to do a series of activities using the e-tutorial during the Mathematics tutorial period. They were given orientation on how to log into the system, access the e-tutorial and access other resources they would have in the regular classroom environment (e.g., a scientific calculator). Also, the researcher, acting as a tutor, was available to assist the students.

7.3.3 Introduction Item

In Cycle 4, the adaptive release was added to the Introduction item, which was an interactive presentation followed by a test. The aim was to provoke students to read the introduction carefully in order to comprehend where to go, what to do and how to do it. Table 7.15 shows the results of students' performance in the introduction test.

Table 7.15: Students' performance in Introduction test

		Status	Grade distribution			
Activity	Count	In progress	< 60	%	>60	%
Introduction	36	0	16	44	20	56

Results indicated that 56% (20 out of 36) of students got 60% in the Introduction test. This suggested that these students studied the Introduction content since they achieved a reasonable level of success in the Introduction test. The issue was partially resolved.

7.3.4 In-class Observation

In Cycle 4, the Quizlets feedback was set to tell the student to ask for assistance after three attempts. The aim was to identify and assist struggling students. Two tutorial assistants were employed for this purpose and to note the nature of requests for assistance.

Table 7.16: Cycle 4 Observation data

Focus area	Observation
1. Student Engagement	1.1 17 asked for assistance in the first session and 13 in the second session.
2. Challenges	Technical 2.2 How to use a computer calculator 2.2 Struggling to resume answering the missing question 2.3 How to insert the signs like multiplication, addition 2.4 How to view marks after activity 2.5 How to go to the next activity Mathematical 2.6 Struggling to correct to the nearest whole number 2.7 Struggling to correct to the two decimal places 2.8 How to find the trig ratio of sine 2.9 How to find an angle given two sides of the triangle 2.10 How to identify the missing side

In-class observations provided insight into the students' actions. Results from the tutorial assistants' notes indicate that students responded to the feedback request to ask for assistance. In Cycle 4, students did rough work on paper and then answered on the computer. A number of scripts were collected for analysis. It was observed that students either wrote neatly or roughly (Appendix 9). Table 7.17 shows a summary analysis of students' scripts.

Table 7.17: Analysis of students' scripts

Activity	Number of scripts collected	Number written	
		neatly	roughly
1	5	1	4
2	34	3	29
3	23	6	17
4	20	6	14
5	25	13	12
6	25	13	13
	132	42	89 (67%)

The analysis of students' scripts indicated that out of the 132 scripts collected, 67% were written roughly.

7.3.5 Journal Responses

As in Cycle 3, all students were encouraged (not forced) to complete a learning journal (Section 4.2.1) detailing their experiences during the tutorial. Again, in Cylce4, the purpose of the learning was clearly explained. This resulted in a reasonable response rate, as summarised in Table 6.34(1).

Table 7.18: Summary of Journal responses

Focus area	Observation
1. Response rates	Activity1: 88%, Activity2 64%, Activity3: 71%, Activity1: 73% and Activity 5: 28% Activity 6: 76%
2. Student Engagement	Excitement 1.1 Interesting: test 50%, Quizlets 48%; Notes 11%; Video 9% 1.2 Challenging: none 48%, Quizlets 33%, test 24%; Notes1%; Video2% 1.3 Frustrating: none 51%, Quizlets 33%, test 24%; Video1%; Notes0% Confidence 1.5 Did activities by self 70% 1.6 Got assistance from tutor 7 % or peers 4% Satisfaction 1.6 Understood topic well (got 75-100%) 84% 1.7 Poorly (got 30% or below) 3% Quizlets feedback 1.7 Was informative 30%, easy to follow 63%,

	1.8 Directed me where to study in resources 10% 1.9 Not clear 7%, was useless 3%
	Sample comments (How did you use the resources?) 1.10 "NOTE, I CHECKED THE EXAMPLES, AND IT WAS NOT DIFFICULT TO UNDERSTAND." 1.11 "I used notes before I read test, to test myself that I have managed to understand my notes." 1.12 "I first watched the video and it gave me a clue of what the activity was about." 1.13 "I USED THE RESOURCES EVERY TIME I WAS STUCK, SO WOULD JUST CLICK ON THE VIDEO SO IT COULD ASSIST ME IN ANSWERING DIFFICULT PROBLEMS." Quizlet Feedback 1.14 "the feedback gives you a hint or information on what you must look at." 1.15 "the quiz made it simple when answering the questions." 1.16"it has shown me where I have forgotten and where I need to study."

Journal responses suggest three types of engagement: 1) student actions, 2) students' feelings, and 3) problems using the system.

1) Student actions

Responses to the open question indicated that students explored content resources before doing Quizlets questions (1.10; 1.11; 1.12) or when they experienced challenges answering Quizlet questions (1.13).

2) Students' experiences

Journal results also suggested that, as in Cycle 3, many (50%) of the students felt that the e-tutorial was interesting (1.1), easy to work with (1.2) and understood the topic well (1.6). These students found Quizlet and Test (doing calculations) more interesting than Video and Notes (1.1). A small number found Quizlet more challenging than Test (1.2). However, they found Quizlet feedback useful (1.14).

3) Problems using the system

A larger number of students (48%) did not experience any challenges while doing the e-tutorial (1.2). However, the rest experienced challenges mainly with Quizlets (33%), tests (24%) and a small number with notes (1%) and videos (2%) (1.2).

7.3.6 LMS Generated Data

In Cycle 4, the following data sets were extracted from the grade centre of the LMS; 1) Students' work samples, 2) Item analysis, 3) Column statistics, 4) Attempts statistics, and 5) Quizlets results.

7.3.6.1 Student work samples

Student work samples indicated that several students made some errors, as captured in Appendix 6.3e. These are summarised in Table 7.19 below.

Table 7.19: Student Error Analysis

Error	Number of cases
Spelling (activity 1 and 4),	13
Not squaring, rounding (activity 2),	8
Solving simple equations (activity 3),	4
Using incorrect information (activity 5).	3

The results suggested that correcting these student errors was part of the learning process.

7.3.6.2 Item Analysis

Table 7.20 shows a summary of Cycle 4 item analysis (section 6.2.7.2).

Table 7.20: Summary of Cycle 4 Item Analysis

Activity	Attempts status		Average performance		Questions	
	Completed	In Progress	Time	Score	Discrimination	Difficulty
Activity1	37	1	8hr01min	85%	4 good 1 fair	3 easy 2 medium
Activity2	35	3	02hr24min	80%	6 good	3 easy 3 medium
Activity3	35	1	00hr21min	84%	3 good 1 fair	3 easy 1 medium
Activity4	34	1	02hr20min	87%	4 good	4 easy
Activity5	36	0	19hr27min	87%	5 good	3 easy 2 medium
Activity6	32	2	00hr29	65%	5 good	1 easy 3 medium 1 hard
TOTAL	209	8		81.3%		

Table 7.20 provided statistics that provided insight into the following three categories of engagement: 1) attempt status, 2) students' performance and 3) question quality.

1) Attempt status

Table 7.20 shows that out of a total of 209 attempts, only 8 (4%) students still need to submit their answers, recorded by the system as *attempt in progress*. This result was below the 7% recorded in Cycle 3 and was within acceptable levels/limits.

2) Students' performance

Students' performance was good since the average score (81,3%) in each activity was above the 60% target. This result was within acceptable levels of performance.

3) Questions Quality

Table 7.20 indicates that there were no questions in all Activities that could be poor discriminators of student performance. Moreover, only one hard question was identified by the system. This result suggested that more students were answering tutorial questions correctly. This implied that the e-tutorial was working well.

7.3.6.3 Column statistics

The Column Statistics displayed statistics for an Activity, represented by a grade centre column, showing how students fared on each Activity and how the grades were distributed. The aim was to see activities where the targeted pass rate was achieved.

Table 7.21 below shows a summary of Column Statistics (section 4.2.4) in Cycle 4 indicating how the grades were distributed.

Table 7.21: Summary of Cycle 4 grade distribution

		Status	Grade distribution			
Activity	Count	In progress	< 60	%	>60	Success rate%
Introduction	36	0	16	44	20	56
Activity 1	38	0	4	11	34	89
Activity 2	38	0	3	8	35	92
Activity 3	36	0	2	6	34	94
Activity 4	35	0	2	6	33	94
Activity 5	36	0	0	0	36	100
Activity 6	32	2	9	29	23	71
						AVERAGE= 84

Summary of Column Statistics, Table 7.23 above, indicates an average success rate of 84% in all activities was achieved. When the students were allowed to review content and try again, some students attempted activities up to four times (see Table 7.22) due to conditional release.

Table 7.21: Summary of the number of attempts per activity

Activity	Number of attempts	Attempt 1	Attempt 2	Attempt 3	Attempt 4	Improved	Dropped	No change
0	42	36	3	3	0	3	0	0
1	49	38	10	1	0	11	0	0
2	45	38	7	0	0	7	0	0
3	45	36	9	0	0	9	0	0
4	40	35	5	0	0	5	0	0
5	46	36	7	2	1	10	0	0
6	49	38	9	2	0	11	0	0
TOTAL	316	257	50	8	1	56	0	0

Results indicate that, in 56 cases, performance improved with each attempt. This resulted in a more than 80% success rate in each activity. These results suggested that the activities were challenging but doable when given a chance to try again.

7.3.6.4 Attempts statistics

System responses in the activities were accessed via attempts statistics.

Table 7.23:.Test-Attempts statistics

Activity	Question	Correct answer (%)	Partially correct (%)	Not answered (%)	a	b	c	d	e	F	g	h	i	j	k
1	1 fmb	92	5	0	95	97	92								
	2 fmb	90	11	0	95	95	95								
	3 fmb	37	61	0	74	63	84	82							
	4 fmb	61	26	0	79	68	76								
2	1 ma														
	2 ma														
	3 ma														
	4 fmb	55	40	5	87	95	87	87	90	90	82	80	82	92	90
	5 fmb	53	42	5	90	84	95	95	95	95	95	61			
3	1 fmb	56	44	0	94	78	67	86							
	2 fmb	58	42	0	97	86	83	78	86						
	3 fmb	42	58	0	75	64	78								
4	1 fmb	63	31	3	80	83	83								
	2 fmb	40	60	0	80	66	74	94	91	100					
	3 fmb	46	54	0	83	71	86	94	89	94					
5	1 fmb	42	58	0	83	78	81	67	92	72					
	2 fmb	31	69	0	86	94	94	53	92	58					
	3 fmb	100	100	0	58	79	75								
	4 fmb	50	50	0	100	97	100	64	94	83					
6	1 fmb	22	72	3	84	84	59	78	78	50	72				
	2 fmb	16	81	3	97	63	72	69	72	53	72	72	72	41	66
	3 fmb	25		3	63	75	69	66	50	94	69	66	44	63	
	4 fmb	0	97	3	69	84	84	84	41	91	81	81	53	6	

System Error Indicator Key

>80	Acceptable student errors	
60-79	System answer error-tolerance	e.g., spelling, syntax
< 60	System answer contains minor errors	e.g., evaluation method: “exact” Vs “contains.”
0	System answer contains significant errors	e.g., wrong

Table 7.23 indicates that there was only one question in Activity 6, with a significant system error or wrong system answers, resulting in 0% correct answers.

7.3.6.5 Quizlets results

The summary of Quizlets results in Table 7.24 compares the number of Quizlet responses with the number of attempts per activity.

Table 7.22: Summary of Quizlet results

Activity	No of attempts	Quizlet Responses	Passes	Fails	Time Range (minutes)
1	36	50	27	23	4.23 – 40.45
2	36	27	27	0	2.38 – 11.00
3	36	24	17	7	2.77 – 14.07
4	35	33	28	5	2.05 – 30.16
5	36	31	31	0	1.14 – 32.03
6	32	13	4	9	3.41 – 18.25
Total	211	178	134	44	
AVERAGE	35,17	29,7 (84%)	22,3 (63%)	7,33	

Summary of Quizlets results in Table 7.24 indicated that most students (average 35 out of 36) tried the Quizlet questions, resulting in an average pass rate of 63%. The higher number of Quizlet responses in Activity 1 (than in the other activities) was probably due to repetitions (due to conditional release control) as students learned to use the system. As a result, these students could do the rest of the activities efficiently.

7.3.7 Summary of Key Results

Level-one analysis of regularly occurring insights into student engagement identified suggested the following local themes:

1) Learning Outcomes: students' performance, students' errors.
2) Student actions: student reading, student strategy, social interaction.
3) Student experiences: frustrations, satisfactions.
4) System use: system affordances, problems in using the system, system shortcomings.

1) Learning Outcomes: students' performance, students' errors.

- Student performance was good since an average success rate of 84% was attained in Cycle 4 (section 7.3.6.3). And the average score in each activity was 81,3% (section 7.3.6.2).

- Student error analysis revealed that students made the same errors (section 7.3.6.1) as observed in Cycle 3 (section 7.2.8.1).

2) Student actions: student reading, student strategy, social interaction.

- Student reading: students effortfully studied the Introduction item content since they achieved a reasonable level of success in the Introduction test (section 7.3.3(1). and the resources (section 7.3.5(1)).

- Student strategy: students worked (neatly or roughly) on the answers on paper before answering on the computer (section 7.3.6.1).

- Social interaction: a total of 30 requests for assistance were made in the first two tutorial sessions (section 7.3.4).

3) Student experiences: frustrations, satisfactions.

- Frustrations: many students (51%) did not experience any frustration, and a small number (33%) were dissatisfied with Quizlets or tests (24%) (section 7.3.5(2)).
- Satisfactions: many students (50%) felt that the e-tutorial was interesting and easy to work with (section 7.3.5(2)).

4) System use: system affordances, problems in using the system, system shortcomings

- System affordances: results suggested that the students could successfully work out the Quizlet questions (section 7.3.6.5), review resources (section 7.3.5(1), and work out the tutorial questions (sections 7.3.6.2; 7.3.6.3).

- Problems in using the system: despite a large number of students (48%) who indicated that they did not experience any challenges while doing the e-tutorial (section 7.3.5(3), many were helped when they experienced technical or mathematical problems (section 7.3.4).

- System shortcomings: there was only one poor quality question in Activity 6 (section 7.3.6.2(3), with a wrong system answer, resulting in 0% correct answers (section 7.3.6.4).

7.3.8 Evaluation of Results

In the Cycle 4 evaluation, the result of each change made during the review process was assessed by contradiction analysis in relation to achieving objectives set during the review process and overcoming the issue.

7.3.8.1 Contradictions analysis

In Tut 4, no contradictions were found within three components of the e-tutorial activity system. The two outstanding issues were resolved in Cycle 4, as discussed below.

7.3.8.2 Evaluations of Cycle 4 changes

1) Introduction

The issue here was poor performance in the introduction test. Cycle 3 results suggested a need to allow students to repeat the Introduction test to achieve mastery of Introduction-item content. To achieve this objective, the Introduction item test was made more stimulating by adding an achievement-based release at the minimum level for passing (i.e., 60%) the test. Cycle 4 results (section 7.3.6.3) indicated a success rate of 56% in the Introduction test. This suggested that students achieved a reasonable level of success in the Introduction test. The issue was partially resolved.

2) Quizlets

The issue was that some students were still struggling to answer the Quizlets. These needed to be identified and assisted. To achieve this objective, Quizlet feedback was set to tell the student to ask for assistance after three attempts. Cycle 4 results (section 7.3.4) indicate that students responded to the feedback request to ask for help, with a total of 30 requests for assistance (section 3.3.7(2)). As a result, these students were assisted with their technical or mathematical challenges.

7.3.8.3 Summary of resolved issues in Cycle 4

Table 7.25 shows a summary of the two issues which were resolved in Cycle 4

Table 7.23: Summary of resolved issues in Cycle 4

Issues arising	Redesign	Results	
	Action	Effect	Evidence
Learning engagement			
1. Introduction Poor performance in the Introduction test	Add adaptive release	Issue partially resolved	56% of students got 60% in the test
2. Quizlet feedback Quizlet feedback was not adequately used Students not paying attention to feedback	Add after 3 attempts: Ask the tutor for assistance.	Students responded to the feedback request to ask for assistance.	Tutors' notes Examples of requests noted by tutorial assistants.

7.4 Summary

This chapter presented Cycle 3 and Cycle 4 results from in-class observations, interviews, questionnaires, screen capture videos, and system-generated data. For each modality, elements relating to students' engagement with the e-tutorial activities were discussed.

1) Learning outcome

Learning outcome results suggested that many students attained a proficient level of success in engaging with the content in all activities (section 7.3.7(1)). This result implied that 1) more students were answering tutorial questions correctly, 2) the design limitations that might have constrained the learning engagement process were minimised and 3) the e-tutorial was working well.

2) Learning orientation

Students' journal statements suggested that most students found doing calculations more interesting than reading but explored the content when they experienced difficulties (section 7.3.5(1). This result implied that most students experienced learning through adaptive rehearsing of problems and exploring of content.

3) Learning engagement

Results suggested that the common elements of student engagement with the e-tutorial activities were 1) student actions (how the students worked with the different components of the e-tutorial learning environment), 2) student experience (students' reaction to the e-tutorial activities), and 3) system use (how students worked with the e-tutorial system).

8 FINDINGS AND DISCUSSION

8.1 Introduction

This project aimed to explore the process of designing and developing an e-tutorial that can support a reasonable process of engagement in the learning of first-year basic trigonometry for engineering at Walter Sisulu University. This chapter presents and discusses the results of 4 activity theory analyses (one for each cycle (see section 5.1)) focusing on the use of and learning from e-tutorial.

8.2 Summary of Key Findings

Chapters 6 and 7 provided details of the data collected in each cycle. From the basic categorisation of data collected through qualitative methods (i.e., questionnaires, interviews, observations, screen capture videos, and journals), local themes of regularly occurring insights into student engagement were identified using Level-one analysis (section 4.4.1), and the results for each cycle, were organised across the data modalities. These local themes were refined to form the following categories.

1) Student profile: age, gender, gap years, computer literacy
2) Student actions: reading, strategy, and social interaction
3) Student feelings: attitudes and frustrations
4) System use: facilitation of the engagement process, challenges while using e-tools, challenges while doing the mathematics, system shortcomings
5) Tools of engagement:- challenging experience, purposeful resource provision, space for graceful failure, conditional release
6) Learning Outcomes: students' performance, students' errors

8.2.1 Student Profile

A total of 129 students (an average of 37 per cycle) completed the student profile questionnaire (see Appendix 12.2), with a slightly higher percentage of male students (64.25%) than female students (44.75%). Most of these students (64.9%) were between 17 and 20 years old; however, students of more than 26 years were also noted.

The student profile questionnaire responses indicated potential subjective data that could influence e-tutorial use. These influences are not the primary focus of the research but rather possible sources of barriers. Student profile questionnaire responses suggested that most of the students (54.5%) had completed their matric the previous year; others had several gap years: one (18.8%), two (12.7%) or more than two (14%). Most students rated their computer experience as Intermediate (55.8%). Others were Novice/Beginner (34.1%) and Expert (10.1%). On average, 68.7% of the students responded to the call to test the system.

8.2.2 Student Actions

The evaluation of student actions in the e-tutorial system focused on understanding how students engaged with the system. Insights from the evaluation were related to accessing and reviewing resources, working out Quizlets and tutorial questions, and interacting with peers and tutors.

The results of the evaluation (sections 6.2.3(1), 6.2.3(4), 7.2.6(1), 7.3.5(1)) suggest that students were more interested in doing calculations than studying multimedia resources. They preferred to answer the tutorial questions first, even if they thought they knew the topic, and only reviewed content resources when they experienced challenges in answering tutorial questions. They also explored content resources when they experienced challenges in answering Quizlet questions.

While working out Quizlet and tutorial questions, students used rough work as a strategy to recall knowledge and to get an idea of how to complete the activity (sections 6.2.3(1), 6.3.5(1), 7.2.4(1)). They preferred to work out the tutorial or Quizlet questions on paper, then input their answer into the computer, comparing their answers with what was on the system. This suggests that writing enabled students to get an idea of how to solve a given problem or activity before completing it online. The rough work also served as a reference point to compare their answers with the system answers.

Social interaction provided students with adaptive support when needed (sections 6.2.6(1), 6.3.8(1), 7.2.7(3)). Through safe verbal communication, they asked for help from peers and tutors, and in some cases, worked out the activities as a group. This suggests that face-to-face social interaction (student-student and student-tutor) provided students with much-needed support through peer tutoring, discussions, and collaboration.

8.2.3 Student Feelings

The evaluation of student feelings refers to how students reacted to the e-tutorial and learning activities. The results of this study suggest that students had two types of feelings towards the e-tutorial: frustrations and positive attitudes.

The results of the study suggest that students experienced some frustrations while using the e-tutorial (sections 6.2.3(4), 6.3.5(2), 7.2.6(2), 7.2.7(1)). These frustrations occurred when system resources were confusing or too long, their responses were consistently marked wrong by the system, or they felt nervous because it was their first time using a computer.Despite these frustrations, most students felt confident and satisfied while working with the e-tutorial (sections 6.2.6(1), 6.3.8(1), 7.2.7(1), 7.3.5(2)). They found the e-tutorial to be interesting, informative, and easy to work with. While some students experienced technical or academic challenges that led to frustration, most students found the e-tutorial to be a valuable learning tool.

8.2.4 System Use

System use refers to how e-learning tools facilitated or constrained the students' engagement with the e-tutorial system. The following themes were identified: affordances of the e-tutorial, challenges while using e-tools, challenges while doing mathematics, and system shortcomings.
Affordances of the e-tutorial (sections 6.2.7.1, 6.3.9.1, 7.2.9.2). The LMS test tool and Quizlets were the primary affordances of the e-tutorial. The LMS test tool facilitated engagement by presenting content resources and tutorial questions, providing space for answering the tutorial questions, and marking tutorial questions and conveying results to the student. Quizlets functioned as rehearsal problems with immediate, elaborated feedback that directed students to relevant sections in the resources.
Challenges while using e-tools (sections 6.2.3(2), 6.3.5(2), 6.3.7(2)). Some students experienced challenges while using the e-tutorial, such as filling in the blanks and correcting mistakes. This was because the system did not cater for abbreviations, alternative answers, typing mistakes, or alternate ways of arriving at the answers. As a result, their input on the computer was consistently marked wrong by the system.
System shortcomings (sections 6.2.3(3), 6.2.6(3), 6.2.7.1, 6.3.5(3), 6.3.7(3), 6.3.9.1(3)). System reviews identified several shortcomings in the e-tutorial, such as the lack of support for abbreviations, alternative answers, typing mistakes, and alternate ways of arriving at the answers. These shortcomings were corrected, making the activities doable and resulting in the achievement of the target success rate.

8.2.5 Tools of Engagement

Caladine (2008) identified the provision of instructional materials and interactions with such materials as two essential tools which can be used to enhance engagement in e-learning. In this study, these tools were made manifest through, purposeful resource provision, creation of challenging experiences, providing space for graceful failure and LMS-assisted learning process regulation.
The results of the study suggest that the provision of distinct levels of resources (big picture items, precession items, and reminder items) was an effective mechanism for purposeful resource provision. This is because only a small number of students experienced challenges

with these resources (section 7.2.7(2)). Quizlets were an effective way to create a challenging experience for students. This is because Quizlets motivated students to review the resources and provided immediate feedback to direct struggling students to relevant sections in the resources or to ask for assistance (section 7.2.7.6(1) and (2)).

The results also suggest that safe verbal communication among students or between students and tutor enabled connection and encouragement through peer tutoring, discussions, and collaboration. This is because students who experienced technical or academic difficulties were able to ask for help from their peers or the tutor, or work out the activities as a group (section 8.2.2(3)). Moreover, providing space for graceful failure supported self-regulation by giving students a chance to try again and providing resources to make a recovery easier (sections 7.2.7(3), 7.3.6(3), 7.1.1.1, 7.2.7.6(1) and (2), 7.2.8.1(2)). This is because the system afforded students with valuable space for 'graceful failure' by providing a chance to try again, accessible resources that foreground detailed precession, and immediate feedback, directing students to relevant sections in the resources or to ask for assistance.

The results of the study suggest that LMS-assisted learning process regulation may have benefitted some students (sections 7.2.8.3,7.2.8.5 and 7.3.6.3). This is because the summary of the number of attempts per activity in Cycles 3 and 4 indicated that some students attempted tests up to four times, and in most of these cases, students' performance improved between the first and last attempts. The analysis of student performance in Cycle 3 and Cycle 4 also suggested that locking progress challenged students to try again, motivated them to think about what they were doing, and encouraged struggling students to improve their performance.

8.2.6 Learning Outcomes

This section aimed to evaluate the effectiveness of the e-tutorial or the extent to which objectives were achieved. In particular, what students could achieve as a result of their engagement in the learning process.

1) Students' performance (sections 6.2.7.3, 6.3.9.3, 7.2.8.3, 7.3.6.3)

In the initial design objectives, it was desired that, in each activity, a success rate of 80% of the students would achieve a competency level of 60% (section 5.2.1). However, in

- Cycle 1: the average of correct attempts per activity was only 7%.
- Cycle 2: a success rate of less than 80% occurred in 5 out of the six activities. Two of these 5 had a reasonable performance with a success rate of 70%.
- Cycle 3: An average success rate of 88% per activity was achieved.
- Cycle 4: An average success rate of 84% per activity was achieved.

Students' performance in Cycles3 and 4 indicated that more than 80% of students got 60% or more in each activity. In other words, the target learning outcome of a success rate of 80% in each activity was achieved.

2) Students' errors (7.4.3(2))

The students' performance results (above) suggested a positive development in e-tutorial design in Cycle 2, but issues relating to entering answers remained to be addressed and corrected. Student error analysis revealed that some students made errors in spelling, not squaring, precision in rounding, solving simple equations, and using incorrect information. These issues were addressed in Cycles 3 and 4, where the LMS's conditional release function was used to lock progress from one activity to another until the student achieved a predetermined pass mark.

8.3 Contextualisation of research findings

Hashim and Jones (2007)) argue that Activity Theory can be used as a framework for qualitative analysis of the individual (subject) in pursuance of their activity and objective through an examination of the tool(s) and its mediation effect in relation to rules, community, and division of labour, regardless of the field of study (Hashim & Jones, 2007). In this research, where the field of study is the use of learning technologies (e-learning) for learning or revising mathematics knowledge in higher education (Scanlon & Issroff, 2005), Activity Theory provided a helpful paradigm and language for understanding how human experience, needs, and creativity shaped the design and effectiveness of emerging technologies.

This study was conducted in the field of e-learning in higher education (broadly) and specifically explored LMS-based teaching and learning (subfield), focusing on students' engagement in an LMS-mediated mathematics e-tutorial. In Chapter 3, Activity Theory was used to generate a fourteen-step model adapted from Jonassen and Rohrer-Murphy (1999), Mwanza (2001), and Khayyat (2016), for the analysis of data. Various related, analytical sub-questions were used to enrich and expand the primary research questions (section 1.5. In this section, the answers to these questions are discussed to characterise the e-tutorial system and specify the analytical context of the study in more detail.

8.3.1 Characterising the e-Tutorial Activity System

This section describes how the Activity Theory was used as a theoretical and methodological lens for characterising and analysing the e-tutorial (Barab et al., 2004). The study adopted the e-tutorial as the learning technology tool in the community of a higher education institution.

Using this Activity Theory framework, the LMS-mediated tutorial system was described by answering questions 1 to 8 in the extended Fourteen-Step Model (see section 3.4.2).

1) The activity of interest

The activity of interest was engaging students in learning basic trigonometry using an LMS-mediated tutorial.

2) Objective; the purpose of the activity

The objective, the purpose of the activity, was learning (the basic trigonometric concepts and skills) through the use of e-tutorial learning activities (see section 5.2.3(2)).

3) Subjects involved in carrying out this activity

The *subject*s involved in this activity were first-year mechanical engineering students (section 8.2.1).

4) Tools used in performing the activity

The students (subjects) performed this activity utilising the e-tutorial (*tool*), made up of: Cognitive tools in the form of teaching and learning resources (see section 8.2.5(1)); Technological tools in the form of LMS tools (see section 8.2.4(1)); and Social tools in the form of scaffolding by tutor and other students (see section 8.2.2(3)).

According to Greasley et al.(2004), an LMS should be able to support learning functions such as computer-mediated communication, content management, computer-assisted assessment and course management. This is possible through appropriating LMS tools adopted, adapted and incorporated into working practice (Ebbert, 2017) in a creative or unusual way (Byrd, 2012). In the context of LMSs, usage appropriation combines the available functionalities to create and structure learning objects, such as courses, modules, tutorials, or activities. In the case of this study, the appropriation of LMS tools to generate the e-tutorial system included using:

- the LMS module tool to create a tutorial structure that enabled sequencing and navigation of e-tutorial activities (section 5.5).
- the LMS test tool to create activities with an open plan structure, where content sections in form of Quizlets and resources were embedded. This allowed students to see and access resources as they did the Quizlet and tutorial questions. In cycles 3 and 4, the test tool also realised the use of the conditional release capability of the LMS to lock progress until a pass mark was attained (section 6.3.10.4).

- the Fill-multiple-blanks question type to enable provision for partial credit for activities (section 6.3.10.2).

5) Rules and guidelines used in regulating performance

The student performance in the e-tutorial activities was based on one set of tutorial questions per activity (section). As the students participated in these activities, they had to abide by the rules and guidelines that were implemented as important by the e-tutorial. Some of these were specified and others were unspecified. These included:

- students' obligations to not only complete the e-tutorial activities but also to submit answers to make it possible for the system to evaluate their performance (section 8.2.4(1)).
- achieve a pass mark of 60% in an activity before going to the next to facilitate learning (section 8.2.5(5)).
- computer laboratory rules that included keeping low noise levels to moderate interruptions by working individually on one computer (section 8.2.5(5)).
- technical regulations for accessing the e-tutorial by logging in with students' credentials to enable the system to identify the student. And logging off at the end of a session to enable the student data to be automatically generated by the system and saved in the grade centre (sections 6.2.7; 6.3.9; 7.2.8; 7.3.6).
- students' obligation to use the proper formats of completing activities by using correct spelling and notation to avoid frustrations when their responses are marked wrong by the system (section 82.3(1)).

6) Community in which the activity took place

The social environment where the activity took place was identified as the class group embedded in the larger university student and learning community. However, since the activity took place within a computer laboratory setting, the 'real' community was the tutorial group, that is, the tutor and the attending students. The students and tutor were the *key* actors within the group, as demonstrated by their responsibilities (division of labour) when carrying out this activity (explained below).

7) Division of labour when carrying out this activity

The division of labour was defined by the roles and obligations of the students and tutor in doing this activity. The students had to do mathematics in response to tutorial activities and assess their learning (section 5.2.2). Their roles as students included supporting each other through peer tutoring, discussions, and collaborations (section 8.2.2(3)). The tutor was an important part of the community by providing extensive support for the subjects (students) (section 8.2.2(3)).

8) Outcome of carrying out the activity

The outcome of this activity was identified as knowledge in the form of basic trigonometry concepts and skills, as indicated by a success rate per activity.

9) The e-tutorial mediated activity System

The e-tutorial moderated activity system was formulated as a single learning activity system with some division of labour between the student and the tutor. The e-tutorial mediated activity system comprised four subsystems: subject-tool-object, subject-rules-object, subject-community-object, and subject-division of labour-object. However, since the students and tutor were the same *vital* actors within the community and division-of-labour subsystems, these two were merged into a student-social environment-object subsystem. Therefore, the analytical context of this study was defined by the three sub-systems, ***s**ubject-**t**ool-**o**bject*, ***s**ubject-**r**ules-**o**bject,* and ***s**ubject-social **e**nvironment-**o**bject*. These sub-systems were used as central themes to interpret the findings of the student's engagement with e-tutorial activities, grounded by the three dimensions of mediation (i.e., *use, regulation,* and *support*) identified in section 3.3.3.

10) Contradictions levels

These were mainly primary contradictions found within three essential components of the e-tutorial mediated activity system. These were inner conflicts between the ideal type of actions (that could realise the activity) and sets of actions in practice (reality) found within a single node (i.e., object, subject, and tool) of the activity. Contradictions occurred within the element *object* when the goal (80% correct attempts per activity) was not achieved in Cycle 1 and Cycle 2 (section 8.2.6(1)). And within the element *tool,* contradictions occurred in the form of shortcomings in the tutorial questions and the e-tutorial system (section 8.2.4(3)). Within the element *subject,* contradictions occurred when students exhibited some unanticipated attitudes and behaviour (section 8.2.2(1)).

Secondary contradictions arising between the relationships between constituent nodes of activity systems were also encountered (sections 6.2.8.1, 6.3.10.1, 7.2.9.1, 8.2.1, 8.2.4(2)). Secondary contradictions occurred between the *subject* and *tool* components of the e-tutorial activity system. And resulted from challenges or difficulties faced by students while using the system. Among the most important contributory factors to these contradictions was that the system was being developed (sections 5.3; 5.4). Other contributory factors were technical issues related to students' limited computer competency (. And others that related to limitations of the LMS tool used (section 8.2.4(2))

8.3.2 Mediational Factors in the e-Tutorial Activity System

The three sub-systems (section 8.3.1(9)) and questions 10 to 14 of the Fourteen-step model (section 3.4.2)) were used to provide the researcher with a deeper understanding of how the students' engagement was impacted by mediational factors. The mediational factors identified were *awareness*, *motivation*, *barriers,* and *environment* (section 3.3.5).

1) Awareness about the subjects' knowledge.

In Cycle 1, it was observed that despite the tutor's verbal presentation of the tutorial objectives, students did not have a clear idea of what they knew, wanted to learn or why they were learning right angle trigonometry. In cycles 2, 3 and 4, pre-tests were introduced, where the student performance provided a good indicator of how much each student knew. Moreover, error analysis of students' performance in tutorial questions suggested that students could solve problems involving the basic form of the right tringle but struggled to solve problems that require the use of detailed properties of the right triangle (sections 6.2.7.2(1); 6.3.9.1(1); 7.2.8.1). Results suggested that students had a big picture of right triangle trigonometry. However, they lacked knowledge of the details (properties and their relationships). Consequently, students needed to become aware that what they knew (the big picture) might not be enough. This *awareness* was realised through three mediational tools: pre-test, Quizlets and pdf resources. Pre-testing established the foundations for future learning by providing students with an understanding of the level of basic trigonometry knowledge required. Conversely, Quizlets alerted students to the need for reading content by creating a demand for knowledge (section 8.2.5(2)). By design, Quizlets supported immediate feedback on a question-by-question basis, which directed students to relevant areas in content in response to wrong answers (section 8.2.5(2))). In addition, the big picture resource items (pdf) provided *awareness* of the scope of the topic (section 8.2.5(1)).

2) Barriers to achieving objectives

Three factors were identified as possible *barriers* to good student performance. First, responses judged as errors could have been due to slips or non-mathematical reasons, such as spelling, not squaring or incorrectly copying values (section 6.3.9 (1)). Secondly, the students faced several challenges with using the system, e.g., filling in the blanks and correcting mistakes (section 6.2.2(2); 6.2.5(2)). Thirdly, shortcomings in the tutorial questions were observed, e.g., abbreviations were not catered for, fill-in-blanks were puzzling, and some of the system answers were wrong (section 6.2.2(3); 6.2.6(1)).

3) Motivators as drivers to achieve objectives

Findings suggested that student motivation was achieved by creating a demand for knowledge through a challenging experience that sparked the engagement process. This helped students to confront their ignorance actively. Motivators which acted as drivers to achieve objectives were pre-tests and Quizlets. Pre-tests were introduced as rehearsal problems in Cycle 2 (sections 6.1.7 and 6.2(3)) to provide students with opportunities to determine their knowledge gaps, thereby determining what content to concentrate on. Quizlets, introduced as rehearsal problems, created a demand for knowledge as the students were provoked to access multimedia resources when stuck and reviewed content to get answers to "experienced challenges" (sections 6.3.4 and 6.4.3) to improve their achievements. This suggested that Quizlets acted as an entry point into content and *motivated* students to access and review resources (section 8.2.1(1)). Moreover, the Quizlet's immediate feedback, on a question-by-question basis, which directed students to relevant areas in content in response to wrong answers, enhanced students' interactions with the resources (section 6.37(3)).

4) Environment in which the activity took place

After improvements were made in the system through system reviews, the students engaged with the e-tutorial learning environment in different ways. These included reading resources, working out Quizlets, tutorial questions and interacting with peers and the tutor (sections 8.2.2(1), 8.2.2(2), 8.2.2(3)). These different ways of engagement could have contributed towards achieving the target learning outcome in Cycles3 and 4.

8.3.3 Summarising the e-tutorial Mediated Activity System

The findings (section 8.2) have been summarised in the display of Figure 8.1.

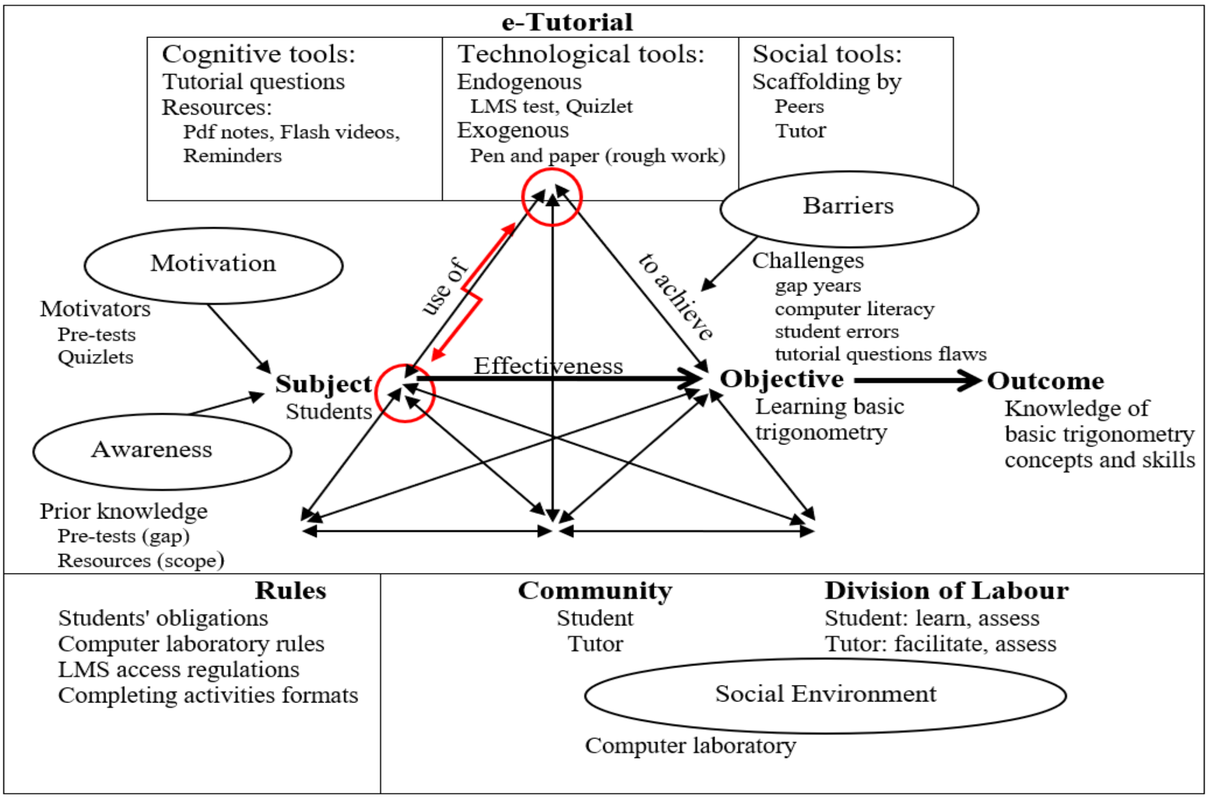


Figure 8.1: The e-tutorial activity system

(based on Jonassen and Rohrer-Murphy (1999), Mwanza (2001), and Khayyat (2016))

The representation above provides a basis for the analytical context of this study discused in the following section.

8.3.4 Analytical Context of this Study

According to the representation above, the student (the ‘subject’) engaged in learning basic trigonometry (the ‘object’) through their interaction with the e-tutorial (the ‘tool’), which was dependent on and influenced by the rules and social environment. This study focused on the role of the e-tutorial in this activity system, not on the functioning of the activity system in general. That is, it focused on the e-tutorial as a mediating tool. The three sub-systems (section 8.3.1(9) and questions 10 to 14 of the Fourteen-step-model (section 3.4.2) provided the researcher with a deeper understanding of how the students’ engagement was impacted by the mediational factors of: *awareness*, *motivation*, *barriers,* and *environment* (section 3.3.5).

1) The student-tool-object sub-system

The *student-tool-object* sub-system involved students’ *use* of the e-tutorial system tools to achieve the objective of learning basic trigonometry. Gedera (2014) refers to this *use* as tool mediation, how the e-tutorial system tools facilitated and shaped the students engagement in learning activities. The e-tutorial system tools included cognitive tools (tutorial questions and resources), technological tools, and social tools (communication) (section 8.3.1(5)).

2) The student-rules-object sub-system

The *student-rules-object* sub-system involved how the students' actions were *regulated* by rules to achieve the objective. This included, but was not limited to, how the implicit or explicit rules and regulations influenced students' engagement in the e-tutorial activities. The rules that regulated the e-tutorial system included students' obligations, computer laboratory rules, LMS access regulations, and completing activities formats (section 8.3.1(5)).

3) The student-social environment-object sub-system

The *student-social environment-object* sub-system involved how peers or tutor supported students' actions to achieve the objective. This included, but was not limited to, community mediation. That is, how peer collaboration and interaction, peer support, and learning from peers influenced students' engagement in learning activities (Gedera & Sampath, 2014). Insights from the results of this study related to student-social environment included peer tutoring, peer help, group work, and tutor support (section 8.2.2(3)). These aspects were facilitated by social interactions made possible by implementing the system in a group setting in the computer laboratory (section 8.3.1(7)), which enabled spontaneous verbal communication among students (since they were sitting next to each other) or with the tutor (asking for help).

8.4 Discussion of Findings

This section is a discussion of the contribution of this research to the field. It is aimed at showing how the insights developed from this research will deepen and extend the knowledge of the field. The discussion of findings is organised with the help of the following sub-questions, which were related explicitly to the research question:

1. ***What is the quality of the student learning afforded by the tutorial system?***
2. ***How does the e-tutorial system design affect the engagement process?***
3. ***How does the e-tutorial system engage students in the learning process?***

The discussion moves from local (like type I developmental research) to global (type II developmental research) where Questions 1) and 2) are local to the e-tutorial in terms of design goals, and question 3) deals with developing knowledge in the field.

8.4.1 Quality of the Student Learning Afforded by the e-Tutorial System

This section aimed to evaluate the effectiveness of the e-tutorial or the extent to which objectives were achieved. In particular, what students could do due to their engagement in the learning process. This provided research-based insights into the first research question:

What is the quality of student learning afforded by the e-tutorial system?

From initial design assumptions, it was expected that 80% of the students would achieve a competent level (60%) in all activities (section 5.2.1). So, was it possible to get most students over this 'competence' hurdle in the tutorial?

This target learning outcome was achieved in Cycles 3 and 4 (section 8.2.6) after improvements were made in the system. These students' performance results in Cycles 3 and 4 suggested a positive development, but issues relating to entering answers into the system had to be addressed. Student error analysis revealed that some students made errors in spelling, not squaring, precision in rounding, solving simple equations, and using incorrect information. These issues were still evident in Cycle 3 (section 7.2.8.1) and Cycle 4 (section 7.3.6.1) and were addressed through the conditional release function of the LMS, which was used to regulate the learning process (section 8.2.5(4)). The resultant achievement of the target performance levels suggested that the LMS-assisted learning process regulation can effectively contribute to improving the quality of learning outcomes..

This study supports the conclusion of Kember et al. (2010), that if the rationale for implementing e-learning through LMS functions is to improve student learning outcomes, the implementation ought to include features in which students engage in learning activities. The e-tutorial is an example of such learning activities. The learning activities can trigger metacognitive and motivational processes devoted to learning process regulation . For example, they might provoke learners to restudy the material to be learned (Proske, Körndle, & Narciss, 2012). However, the quality of the learning experience is determined by the authenticity of the teaching material employed in the teaching-learning process (Babu, 2018). The use of appropriate teaching material attains highest importance when the target learning outcome is gaining relational understanding (knowing what to do and why) of the topic (Biccard, 2019). Relational understanding requires a clear link to be established between the e-learning pedagogy adopted and the target learning outcome in order to promote understanding (Tanveer, 2011). This objective was achieved through the LMS conditional release function which allowed students temporary relief from a failure in order to enable them to try again and get better results (Fisher et al., 2014) through reviewing and restructuring (Sumule , Sumule, & Fuad, 2018).

8.4.2 Impact of e-Tutorial System Design on the Engagement Process

This section aimed to evaluate the design of the e-tutorial, notably how e-tutorial tools facilitated or constrained the engagement process and the role of these tools in resolving contradictions/disagreements between different goals. This provided research-based insights into the second research question:

How does the e-tutorial system design affect the engagement process?

Results suggested a new insight into how using an LMS and a combination of e-tools (i.e., Quizlets, resources and tutorial questions) generated a problem-oriented e-tutorial system *environment* which facilitated adaptive rehearsing and exploring of content as well as regulating of learning. Including (embedding) the e-tools in the LMS test tool allowed it to not only be used flexibly as a learning environment but also to constrain movement forward by conditional release (section 8.2.4(1)). Additionally, including Quizlets and using them as entry points to the learning resources *motivated* students to access and review resources (section 8.4.1.1). Combining the test tool with Quizlets ensured and deepened real engagement by stimulating the student's self-directed study process.
The test tool was used to develop Learning-activities based on the content objectives(section 5.4.3, (Table 5.7)). Findings indicated that the strength of the LMS test tool was its role as the primary facilitator of the engagement process. It provided a technical *environment* in which content was presented (resources) and learning assessed (tutorial questions). The LMS test tool was used to i) present tutorial questions, ii) provide space for answering, iii) mark tutorial questions, iv) convey results (section 8.2.4(1)) and v) regulate the learning process (sections 8.2.5(4); 8.4.1(5)). However, a significant shortcoming of the LMS test tool (noticed in Cycle 2) was its inability to give immediate (question by question) feedback to guide students as they worked (section 6.2.7.4). This issue was addressed by introducing Quizlets that gave quick (question by question) feedback to enhance learning (Dihoff et al., 2004). The strength of the Quizlets was the immediate feedback to students indicating whether they were on the right track and prompting strugglers to ask for help and get assistance from peers or tutor (section 8.3.1(5)). This resulted in the Learning model change from theory oriented to problem-oriented, where Quizlets became the core of the learning process (section 6.3.10.4). Nonetheless, some of the students struggled with answering the Quizlets questions despite the elaborate feedback per question and needed to be identified and assisted (section 7.3.7.292)).

These results build on existing evidence that the appropriate use of technologies can support and motivate students toward success (Poloju & Naidu, 2020). The e-tutorial is an example of a self-directed study process (Āriņa, Koķe, & Jansone-Ratinika, 2017). The success of this method is based on students' understanding, mastery and personalization of the common objectives (Kattayat, 2022). What was important here was the measures the researcher took to encourage the self-directed study process. In that regard, the e-tutorial, through the Quizlets, made use of the Immediate Feedback Assessment Technique to provide personalised positive and corrective feedback to students in real time as they worked (Marwan, Gao, Fisk, Price, &

Barnes, 2020). This was supported by resources which provided students with adaptive support when needed in the form worked examples which were easy to access (Toukiloglou & Xinogalos, 2023).

8.4.3 e-Tutorial System Engagement of Students in the Learning Process

This section aimed to identify how the themes that emerged in the initial results presented earlier in Chapters 6 and 7 provided research-based insights into the third research question:

How does the e-tutorial system engage students in the learning process?

To answer this question, the key findings were interpreted using the dimensions of engagement in relation to the elements of Activity Theory that acted as mediators of student engagement. The three sub-systems (section 8.2.2) and questions 10 to 14 of the Fourteen-step-model (section 3.4.2) provided the researcher with a deeper understanding of how the mediational factors (i.e., *motivation*, *awareness*, *barriers,* and *environment*) (section 3.3.5) impacted students' actions in the dimensions of engagement (section 3.3.2):

1. Content Engagement through creating a demand for knowledge.
2. Task Engagement exploiting a pen and paper rough work strategy
3. Social Engagement through safe verbal communication.
4. Affective Engagement: through graceful failure and recovery.
5. LMS-assisted learning process regulation of mathematical engagement.

8.4.3.1 Content engagement through creating a demand for knowledge

The development of content engagement in the e-tutorial evolved from a theory-first approach (aligned with Gagné's model of instructional design; section 2.4.3.1) in Cycles 1 and 2 to a 'challenge first' approach (aligned with problem-based learning and challenge-driven instructional design, section 2.4.3.4) in Cycles 3 and 4. The theory-first approach starts with reviewing content to access relevant knowledge, which students use to answer the tutorial questions. Conversely, the challenge-first approach starts with a problem in which triggers from a challenge create a demand for knowledge in order to answer the tutorial questions. Findings suggested that by creating a demand for knowledge, the e-tutorial deepened engagement by stimulating the self-directed study process of actively reviewing and processing information. This indicates that if you can get students to discover their lack of knowledge and that this is a disadvantage for achieving their goals, they can commit better to learning. This challenged the 'theory first' model (section 5.2.2), which assumed that students would first study the resources and then answer tutorial questions (section 5.3.1).

This study did not explicitly examine the reasons for the observed students' disposition (there may be many different reasons), but it showed that this was the approach most students took. There were two mediational factors which could have impacted content engagement: *awareness* and *motivation* (section 8.3.2). Many students did not know the topic well (sections 6.3.2; 7.2.3), although they thought they knew it (6.2.2; 6.2.3, 6.3.4; 6.3.7). Hence, there was a need to generate students' *awareness* that what they knew might not be enough, and they needed the *motivation* to read the resources.

Awareness was achieved through two mediational tools, pre-testing and resources. Pre-testing was introduced in Cycle 2 to assist students in identifying their knowledge gaps. Evaluation of pre-test results in Cycle 3 (section 7.2.9.2) suggested that the pre-test was a reasonably precise indicator of students' prior knowledge. And student performance was a good indicator of how much each student knew (section 7.2.3). Pre-testing provided a means that allowed students to establish the foundations for their future learning. Building on this awareness, big-picture resource items (Pdfs) provided the scope of the topic (section 8.2.5(1)) and allowed students to identify the components of the tutorial that would help them overcome their knowledge gaps. Unfortunately, students could not choose which components to do due to the linear nature of the e-tutorial, controlled by the LMS conditional release function (section).

Gee (2005) emphasises the importance of the observation that human *motivation* lies in challenges that are accessible, although challenging, and in gaining continual feedback that indicates their progress. *Motivation* was achieved through Quizlets by creating a demand for knowledge through a challenging experience that sparked the engagement process (section 8.3.2(3)). The students were provoked to access multimedia resources when stuck and reviewed content to find answers to improve their responses to these "experienced challenges" (sections 6.3.4 and 6.4.3). This suggested that Quizlets acted as an entry point into content and *motivated* students to access and review resources (section 8.2.1(1)). Moreover, Quizlet's immediate feedback, on a question-by-question basis, directed students to relevant areas of content in response to wrong answers, enhancing students' interactions with the resources (section 6.3.7(3)). According to Wood (2003), this process enhances critical appraisal and content review and encourages ongoing learning.

The demand for knowledge (created through pre-tests and Quizlets) corresponds with the principle of challenge-driven Instructional Design (Swan, 2008). According to Swan, a challenging task, set in a context that provides the means and embedded helps to support students' actions, creates a situation in which students can exercise and develop their work. In addition, the results support Byrd's finding that online quizzes can effectively engage students to read assigned material (Byrd, Using Appropriate E-learning Systems to Optimize Teaching and Learning., 2012). When students fail, they are provoked to review content to get answers to experienced challenges, providing an entry point into the content. By design, the Quizlets yielded immediate, question-by-question and elaborated feedback that provided guidance as the student answered the questions (Hattie et al., 2007; Louwrens & Hartnett, 2015). However, the immediate, question-by-question feedback function was unavailable in Blackboard LMS. To overcome this issue, Quizlets were created using quiz software (QuizCreator) and deployed as flash video, embedded in the instructions section of the test tool of the LMS. This is problematic because flash video technology is being phased out and replaced with a more adaptive HTML5.

This study suggests that Gagné's first three events (i.e., gain attention, inform students of objectives, stimulate recall of prior learning; see section 2.4.3.1) can be simultaneously enacted in an LMS-mediated tutorial through pre-testing to reveal the student's competency level in a given topic and using Quizlets to open up the area for exploration. This study presents pre-testing and Quizlets as an alternative to the typical way of motivating the students through introductions stating the aims and objectives (Gagné et al.,1992) or via text or multimedia (Vicente, 2002).

8.4.3.2 Task engagement using pen and paper rough-work

Students' task engagement required a balance between the two types of learning tools, endogenous tools and exogenous tools (section 2.3.3). Endogenous tools involved the built-in features of the LMS that supported student learning. Conversely, exogenous tools were any other learning tools used by students outside of the LMS.

The initial design conceptualisation saw endogenous tools (tests and resources) as sufficient for task engagement. However, working with endogenous tools was cumbersome, prone to mistakes (section 6.2.7(1); 6.3.9(1); 7.2.7(3)) and frustrating (section 6.2.3(4)). Students experienced minor student errors (such as spelling, not squaring or copying values incorrectly), which resulted in responses being marked wrong, and challenges with using the tools (e.g., filling in the blanks and correcting mistakes). These made working endogenously difficult (sections 6.2.6(3); 6.2.7(1); 6.3.9(1) and 7.2.7(3)). As a result, students used exogenous tools (pen and paper rough work) to solve the problems before completing them online. The consistent use of pen and paper for rough work was a good strategy because of its ease and flexibility. Rough work enabled students to get an idea of how to solve a given tutorial question before completing it online.

The use of exogenous tools supports Kirch's (2010) argument that people need to create external structure when thinking "because it is easier to process more efficiently and more effectively than by working inside the head alone" (Kirsch, 2010, p. 443). Rough work also structured thinking by providing a reference point for students to compare their answers with the system answers (external memory) (Vygotsky, 1978). Rough work did not only provide external representations (evidence) of the thinking process used by the students as they answered the questions. It also enabled students to manipulate their computations to understand their content through operative writing (Krämer, 2003). However, since the activities were in a test format, some students may waste time presenting neatly written work samples.

On the other hand, the use of endogenous tools realised the use of the conditional release capability of the LMS to lock progress until a pass mark is attained. This regulated the students learning process to give them a chance to develop and refine their knowledge (Fisher et al., 2014).

This study suggests that the students' strategy to do rough work while doing mathematical tutorial activities can be extended to LMS-mediated tutorials to enhance task engagement. In that context, task engagement is about using multiple tools as and when suitable, not replacing one with another. The flexible and balanced use of these tools enables the students to individualise their approach according to their level of prior knowledge, expertise, and interests (Kalyuga, 2005;)

8.4.3.3 Social engagement through safe verbal communication

The e-tutorial took place in a computer laboratory setting. The resultant social interaction (student-student and student-tutor) provided students with adaptive support, when needed, through safe verbal communication. This individual work with community mediation in a group setting deepened engagement by enabling connection and encouragement through peer tutoring.

The Initial design assumptions presumed that students would be able to work individually since they would have all they needed to complete the tutorial on the computer. However, the students faced several challenges while using the system, e.g., filling the blanks, correcting mistakes, and consistently getting wrong answers (section 8.2.4(2)). There was a need to identify and assist struggling students in overcoming these challenges. This was difficult to achieve in a large class. Still, when students experienced technical or academic difficulties, some asked for help from their peers or the tutor, and others worked out the activities as a group (section 7.4.1(3)). The discussions (student-student and student-tutor) provided them with much-needed support (section 8.2.2(3)). These insights from the results of this study suggested face-to-face community mediation (section 8.3.3(3)) as an important mediator of social engagement.

Mediational tools related to community mediation included peer tutoring, peer help, group work, and tutor support (section 8.2.2(3)). These aspects were facilitated by social interactions made possible by implementing the system in a group setting (a computer laboratory). This enabled spontaneous verbal peer communication since the students sat beside each other. This shows a student as an individual and a member of a larger community (Baran & Cagiltay, 2010). Contrary to the current e-learning trends, indicating a tendency toward physically separated work with computer-enabled social contact, this study supported what other researchers have found, that collaborative face-to-face learning with peers still provides an important contribution to learning (Korhonen et al,, 2019). The students in this study used verbal representation (Lowrie et al., 2018) as external representation to discuss and try to understand the problems they were working on. The discussions acted as a support mechanism for the student's cognitive processing when engaging in the activities. Thus, these discussions were also a form of exogenous tool that enabled connection and support through peer tutoring and exchanging ideas or experiences, as well as developing and discussing new responses and giving feedback (Vrieling et al., Van den Beemt, & De Laat, 2019)

This study suggests that it is important to consider the power and utility of face-to-face verbal peer communication for designing and implementing an LMS-mediated tutorial in contexts such as universities where opportunities to work in a group setting can be created.

8.4.3.4 Affective engagement by supporting self-regulation

The e-tutorial afforded students a useful space for graceful failure and safe recovery as they struggled with challenges while using the e-tutorial, which resulted in frustrations. Graceful failure was achieved by giving students a chance to try again, purposeful multi-level demand-driven resources as embedded support and immediate feedback to provide just-in-time instruction.

A chance to try again allowed students temporary relief from failure. Trying again appeared to enable students to pay attention to what they were doing and to note and rectify their errors and so improve their results (sections 7.2.8.5; 7.3.6.3). The purposeful, multi-level demand-driven resources (section 8.2.5(1)) enabled spontaneous access and review of content, thus making recovery easier. Students were able to freely review the shortened video clips as they answered Quizlet questions to gain insight into how to work out the given activities. In addition, different levels of resource provision mediated different functions; for example, big picture items (e.g., pdf notes) provided awareness, and precession items (e.g., video clips) provided details (section 7.3.4). The design strategy of including examples of model answer items (e.g., hints on answer format) seemed to improve the accessibility of the system. Immediate feedback guided students by directing students to relevant sections in the resources. It was also used to inform struggling (failing more than three attempts) students to ask for assistance.

Results suggested that most students felt confident and satisfied while working with the e-tutorial. They thought the e-tutorial was interesting, informative, and easy to work with (section 7.4.2(2)). However, this may not have been a true reflection of their experience (students may have misjudged their experiences). Students struggled with challenges while using the e-tutorial (sections 7.4.3(1); 8.4.2(2)), which resulted in frustrations. Gedera and William's (2016) study reported similar learner frustration and tension when experiencing difficulty in using technology (downloading podcasts). In addition, the results of this study agree with previous research that while technology plays a significant role in maintaining student interest, technological challenges can not only demotivate students (Dubey, Piroska, & Gautam, 2019), but can also negatively impact students' affective engagement with the learning activities. These challenges or *barriers* (section 8.3.2), which negatively impacted students' affective engagement, were addressed through system reviews.

These results demonstrate three strategies (chance to try again, accessible resources and immediate feedback) used to embed engagement techniques into the instructional design process (Turnbow & Roth, 2019). A chance to try again enabled or assisted struggling students to improve their achievements. The purposeful selection of resources acted as embedded support tuned specifically to the needs of the tutorial users. These multi-level demand-driven resources informed and guided students through the activities. Immediate feedback provided just-in-time assistance to keep the students on task. Students use this continuous feedback information to effectively modify their learning.

The LMS automated assessment supported the implementation of the engagement techniques to afford students a useful space for "graceful failure" and recovery (Fisher et al., 2014; Gardner et al., 2011) which can be of immense use to students (Gakibayo & Okello-Obura, 2013).

8.4.3.5 Mathematical engagement by LMS-assisted learning process regulation

Whereas lecturers typically provide pedagogical support for students learning process regulation, this study indicated that in the case of an LMS-mediated tutorial, the LMS could assist in supporting learning process regulation through conditional release. The conditional release provided process regulation as the students needed to demonstrate mastery of a concept before moving forward.

The summary of students' results indicated that students faced several challenges while doing mathematics (sections 8.2.4(3); 8.2.6(2)). These challenges acted as *barriers* to achieving a passing mark (section 8.3.2). The students had to be supported to overcome these challenges and encouraged to achieve the targeted passing mark. This support was achieved by regulating the learning process through the LMS conditional release function (section 7.2.9.1(3); 7.3.6.). The conditional release provided process regulation through strong control. This deeply influenced achievement because, without achievement, no progress was allowed.

Educators have long recognised the value of students mastering material before moving on to new material. Today, LMSs can provide a means to facilitate this level of control through the use of conditional release of course material (Fisher et al., 2015). Using the best practice recommendations outlined by Gardner et al. (2011), the release conditions were set in the LMS at the minimum passing level of 60% (section 5.2.1(3)). The LMS provided objectivity since answers to the tutorial questions were marked automatically (Pavlenko et al., 2020). This enabled the students to spontaneously receive their results and naturally repeat an activity they failed. This assessment process and the continuous flow of information about student achievement that it provided assisted in advancing student learning. Additionally, automatic feedback reduces the experience of being judged by someone else and thus may reduce the emotional impact of feedback about mistakes.

Locking progress was a helpful way to maintain the mathematical engagement of struggling students who most benefit from a guided learning experience (Darby & Lang, 2019). The conditional release evoked self-assessment and self-reflection (Wang, 2017) and challenged the students to pay attention to what they were doing, note and rectify errors, and complete the activities correctly and accurately to progress. However, a limitation of the LMS conditional release function was that it did not allow the students to see the complete set of activities to be done (see Appendix 1.3(e)).

In this chapter, the Activity theory was used to characterise the e-tutorial as a single learning activity system with some division of labour between the student and the tutor (see Figure 8.1), made up of three subsystems (***s**ubject-**t**ool-**o**bject*, ***s**ubject-**r**ules-**o**bject,* and ***s**ubject-social **e**nvironment-**o**bject*). These three sub-systems defined the analytical context of the study. Analysis of students' engagement suggested that the e-tutorial system engaged students in the learning process through:

1. creating a demand for knowledge, which deepened engagement by stimulating the self-directed study process of actively reviewing and processing information.
2. writing on paper and then capturing on the computer, which deepened engagement by structuring thinking and providing external memory.
3. safe verbal communication, which deepened engagement by enabling connection and support through peer tutoring.

4. useful space for “graceful failure”, which deepened engagement by supporting self-regulation, giving students a chance to try again, and resources (mediating different learning functions) to make recovery easier.
5. regulation of the learning process through combining conditional release with a chance to try again, which enabled the students to think about what they were doing and encouraged struggling students to improve their performance.

As a result, students could develop or refine their knowledge of basic trigonometry through adaptive rehearsing and exploring of content using Quizlets and short, topic-focused resources. By Cycle 4, students could use the knowledge meaningfully by answering tutorial questions, with an 80% (or more) success rate in all activities. This target learning outcome was achieved through using a combination of e-tutorial tools (i.e., Quizlets, resources and tutorial questions), packaged as an LMS test, which deepened engagement by generating the tutorial system components and tutorial structure that provided, navigation interface, activity structure and tutorial question structure.

8.5 Summary

This chapter presented and discussed the results of this study. The finding indicated that the mediational factors (i.e., *motivation*, *awareness*, *barriers,* and *environment*) impacted students' engagement through creating a demand for knowledge (content engagement), exploiting a pen and paper rough work strategy (task engagement), safe verbal communication (social engagement) graceful failure and recovery (affective engagement) and LMS-assisted learning process regulation (mathematical engagement).

9 CONCLUSIONS, CONTRIBUTIONS AND RECOMMENDATIONS

9.1 Introduction

This study explored the design and development of an LMS-mediated tutorial to enable students' deep engagement in revising basic trigonometry. The aim was to generate generalisable principles to guide the design of similar e-tutorials by finding the answer to the following research question:

What are the guiding principles about learning to design an effective e-tutorial for deep engagement (and why)?

Answers to this question were developed and discussed in Chapter 8, based on the design and implementation results presented in Chapters 6 and 7 and ideas emanating from the literature review presented in Chapter 2. The findings arise from transformations of the e-tutorial system developed in research Cycles 1 to 4. The data-driven (empirical/research-based) nature of these findings suggested that these transformations were not about the design process but were about learning enabled by the system. The transformations were mainly related to changes in the initial conceptual model and e-tutorial design that signalled (or required) a modification in the model of learning on which the e-tutorial was based. Furthermore, it contributed to the deepening of the student's learning engagement. This deepening was visible in the data in the form of how the students approached and worked out the e-tutorial activities. The discussion of the findings highlights the main difference between students' learning model and person-LMS interaction: LMSs *do not provide or require a rapid adaptive response, but people are built to deal with an environment that requires and provides a fast adaptive response*.

This chapter begins with conclusions from the previous chapter's discussion, organised according to the key findings. These conclusions are followed by the significance and contributions to the research of these findings, the limitations of this study and some recommendations for further research.

9.2 Conclusions

A summary of the findings of the study is presented below. Each finding is presented in the form of a final design principle which was explicitly chosen to guide the design and development of the e-tutorial in the fourth cycle. This is contrasted with an opposing design principle that guided the design and implementation of earlier versions of the tutorial. Five key design principles have been identified in this research resulting from the following changes:

1) from "Read first, then do" to "Do first, read when necessary."

2) from "Work on the computer" to "Work on paper then capture on the computer."
3) from "Physically separated work with computer-enabled social contact" to "Individual computer work in face-to-face social settings."
4) from "Single-level of resource provision" to "Multi-level, demand-driven resource provision."
5) from "Self-regulated" to "Computer-assisted" learning process regulation

1) From "Read first, then do" to "Do first, read when necessary."

This change deepens content engagement by stimulating the self-directed study process of actively reviewing and processing information.

The initial design assumptions and learning process model ("read first, then do") did not adequately represent the observed learning process. The issue was that students did not review the resources. They appeared to spend more time doing tutorial questions than reviewing resources. These findings suggested that the e-tutorial design required a *motivation* element to activate the reading of resources. The *motivation* was achieved through Quizlets, which created a demand for knowledge through a challenging experience that sparked the students' interactions with the resources (i.e., the content engagement process). The *motivation* element was enhanced by Quizlet's immediate feedback, on a question-by-question basis, directing students to relevant sections in content in response to wrong answers (section 8.3.2(3)). The Quizlets' feedback functioned as performance support tools, which provided "just-in-time" instruction that informed and guided students within the e-tutorial activities (Turnbow & Roth, 2019).

Student engagement data showed that assuming they would "read first" was a flawed assumption, and the design based on this assumption did not engage students effectively. The "do first" design was required to get the students to read the information if the results from doing first showed it was needed. A more appropriate assumption was that most students did not want to read (and did not want to read first). If they are not motivated, the reading is not going to happen.

The Quizlets functioned as an entry point into the content that aligned well with the actual content engagement of the students. This overcame the contradiction between the observed lack of initial reading of the content resources (expected in the "read first then do" learning process model) and the need to read resources that students needed for effective task engagement. In addition, students who did not need to read to engage effectively with the task were not required to when doing the tutorial.

2) From "Work on the computer" to "Work on paper then capture on the computer."

This change deepens task engagement by writing or drawing flexibly to structure and organise thinking and construct external memory.

Findings suggested that working directly on the computer (e-tutorial system) using mathematical computations was cumbersome and prone to mistakes. Students struggled with challenges such as filling in blanks, correcting errors and consistently entering responses marked wrong by the system, which resulted in frustrations (section 7.4.3(1)). In response, students used their writing (rough work) to prepare their answers before submission. This helped them to think about how to formulate their solutions so that the computer could accept them (section 8.4.1(2). Also, rough work offers speed, ease and flexibility when neatness is unimportant. So, writing was not only a positive enabler for creating external structure when thinking but also allowed the students to overcome system input constraints. Consequently, designing for writing could help deepen task engagement.

3) From "Physically separated work with computer-enabled social contact" to "Individual computer work in face-to-face social settings."

This change deepens social engagement by enabling face-to-face contact, connection, and support through peer tutoring when needed.

Students who did individual computer work on the e-tutorial experienced technical or academic challenges. Some students sought help from their peers or the tutor, and others worked out the activities as a group (section 8.2.2(3). Students talked to each other and did some problem-solving together because it was a convenient and powerful way for them to resolve technical or academic challenges. The resultant social engagement provided them with quick, much-needed support (section 8.4.1(3)). This social engagement was enhanced by the computer laboratory environment (in which the e-tutorials took place), facilitating verbal communication, and allowing fast, adaptive, and responsive social querying. So, in a university tutorial context, the physical group setting can provide a valuable and essential social resource which could be incorporated into the design considerations.

4) From "Considering single-level of resource provision" to "Multi-level, demand-driven resource provision."

This change deepens affective engagement by allowing the mediation of different learning functions and supporting easy access to appropriate resources and content review.

Most students preferred to answer problems first and explored the content to look for answers when they failed. These students needed support to easily access appropriate resources and review content in order to try again. They needed just-in-time information to guide them through a task. Therefore, it made sense to include performance support in the form of demand-driven and purposeful resource provision (see section 8.2.4(1)) to enable flexible and direct access to content. Resources had to be short, topical and focused on easing the access and review of content. The different levels of resource provision also mediated other functions. For example, big picture items (e.g., pdf notes) provided awareness about the scope of the topic, precession items (e.g., video clips) provided section-by-section details, and the design strategy of including hints on answer format improved the accessibility of the system.

In these ways, multi-level, demand-driven resource provision allows students to not only individualise their starting point depending on their prior knowledge and expertise but also to improve their knowledge and fill their knowledge gaps more precisely.

5) From "Self-regulated" learning process regulation to "LMS-assisted" learning process regulation

This change deepens mathematical engagement by providing a useful space for "graceful failure" and safe recovery.

As mentioned in section 9.1(4), most students preferred to solve problems first and explore the content to look for answers when they failed. Moreover, the students struggled with interface challenges while using the e-tutorial, such as how to fill in blanks and correct mistakes that resulted in responses being consistently marked wrong by the system. The system needed to provide the students with a useful space for graceful failure and safe recovery. This provision was achieved by locking progress (conditional release) which challenged students to pay attention to what they were doing, note their errors and complete the activities correctly and accurately in order to progress. The system afforded students a useful space for safe recovery by providing a chance to try again, enabling or assisting struggling students in improving their achievements (section 8.2.5(3). The chance to try again was supported by accessible resources that foreground detailed precession (section 8.2.5(1) and immediate feedback to direct students to relevant areas in the resources or to ask for assistance (section 8.2.5(2). This system-regulated interim failure can open up an opportunity for learning, where students can review resources and try again, thus enabling the students to achieve the target performance levels.

9.3 Contributions to Research

This research supports Mamun's (2017) finding that despite the inherent limitations manifest in the online context, scaffolded learning modules can provide a proximal learning environment for online learning. It contributes to the ongoing deliberations on utilising technological resources, particularly through LMS-mediated tutorials. This research's knowledge gap lies in its context of understanding LMS-based teaching and learning, focusing on students' engagement in an LMS-mediated tutorial that enables students' deep and effective engagement in the learning process of fundamental trigonometry.

Ma and Harmon (2009) recommended that two sets of principles grounded in a design-based research study should be provided. First, a set of guidelines for practitioners regarding the research findings related explicitly to instructional innovation to improve their practices. Secondly, a set of principles for researchers interested in conducting design-based research on how to conduct design-based research is based on the reflections on the research methodology (Ma & Harmon, 2009). The product, the practical output of the study, can also be taken as a significant contribution or outcome of a design research study (Herrington et al., 2007). The product was a design artefact in the form of the e-tutorial system developed by the researcher. Thus, contributions to research by this study were in the form of the following:

1) Design Principles for LMS-mediated tutorials
2) Principles for e-tutorial development methodology
3) The LMS-mediated tutorial system

9.3.1 Design Principles (DP) for LMS-mediated Tutorials

The key findings in Section 9.2 are mostly related to changes in the e-tutorial that signalled (or required) a change in the model of learning on which the e-tutorial was based. Therefore, the general design principles can be formulated as characteristics of the learning model, which formed the fundamental basis for the LMS-mediated tutorial.

To enable students' deep and effective engagement in the process of learning fundamental trigonometry within an LMS-mediated tutorial, one needs to design the system with activities that create a demand for knowledge, encourage rough work (writing) and face-to-face social interaction, supported by multi-level, demand-driven resources, and LMS-assisted learning-process regulation.

DP1: Create a demand for knowledge

This principle specifies a learning model based on the process of "do first, read when necessary" rather than "read first, then do." This deepens content engagement by stimulating the self-directed study process of actively reviewing and processing information. It is achieved by creating the demand for knowledge through a challenging experience that sparks or encourages the content engagement process.

This principle is about creating a challenging experience that motivates students to actively confront their ignorance as they use triggers from the challenge to define their learning objectives. In this study, the e-tutorial motivated students at two levels: 1) the pre-test, to see the need to do the tutorial, and 2) the Quizlet, to see the need to actively improve their knowledge by reviewing content as they answered the tutorial questions.

The benefit of pre-testing is its priming effect for what is coming later. Failure on the pre-test is an example of *failing well,* as it sets students up for better learning during the tutorial (Hall, 2017). Based on the student's current knowledge and skills, this provides a good starting point and motivation for learning (Vygotsky, 1978). A pre-test deepens engagement by making students aware that what they know is not enough. However, a pre-test in an LMS environment should use simple question types (i.e., multiple choice, fill in blanks and matching) to reduce the challenges of working on the computer for first-time or novice computer users.

Quizlets are used as entry points into content to motivate students to access and review resources to promote active engagement with that content. The results support Byrd's finding that online quizzes can be effective as a method for engaging students to read assigned material (Byrd, 2014). When students fail the quiz, they are provoked to review content to get answers to experienced challenges, thereby providing the entry point. By design, Quizlets should yield immediate, question-by-question and elaborated feedback that guides students as they answer the questions (Hattie & Timperley, 2007; Louwrens & Hartnett, 2015). However, the immediate, question-by-question feedback function is unavailable in the LMS system (Blackboard). Thus, Quizlets were created using quiz software (e.g., QuizCreator) and deployed as flash video, embedded in the instructions section of the test tool of the LMS. This may become problematic because flash video technology is being phased out and replaced with a more adaptive HTML5.

This study suggests that Gagné's first three events of instruction (i.e., gain attention, inform students of objectives and stimulate recall of prior learning, see section 2,4,3,1) can be simultaneously enacted in an LMS-mediated tutorial by creating a demand for knowledge to spark the engagement process, stimulating the self-directed study process of actively reviewing and processing of information. This may be done through pre-testing to reveal competency level in a given topic and using Quizlets to open up the area for exploration. In this way, students discover their lack of knowledge and that this is a disadvantage for achieving their goals, and in response, they commit better to learning.

DP2: Encourage rough work on paper, then capture on the computer.

This principle specifies a learning model incorporating "work on paper then capture on the computer" rather than "work on the computer." This deepens engagement by providing a flexible and efficient means to structure thinking and generate external memory. This can be achieved by encouraging rough work on paper and capturing the answers on the computer. Rough work creates an external representation that can serve as a shareable object of thought which is easier to process more efficiently and effectively than working inside the head alone (Kirsch, 2010). The ways by which this external representation can enhance cognitive power include, but are not limited to, providing structure, generating persistent referents, and facilitating re-representation, which help to coordinate thought and allow people to think more powerfully with external representations than without (Kirsh, 2017).

This principle is about the flexible use of multiple tools: endogenous e-tools (Quizlets and resources) and exogenous physical tools (pen and paper), as and when suitable to deepen task engagement. It is not about replacing one with another; it is about the complexity of the translation mechanism between tools. The rigidity of the e-tutorial is offset by the flexibility of pen and paper, which provides external memory (Vygotsky, 1978) to mediate the process of completing activities online. This enables the students to individualise their approach according to their prior knowledge, expertise, and interests. This principle is important for mathematics which uses many different representational forms that are difficult or time-consuming to construct on a computer. It may be less critical for subjects that are more text intensive.

The provision for rough work can be made by giving students a rough paper to work on and prompting them for this in the tutorial instructions. However, since the activities were in a test format, some students may waste time presenting neatly written work samples.

DP3: Encourage *face-to-face* social interaction and peer communication

This principle specifies a learning model incorporating individual computer work in face-to-face social group settings rather than physically separated work with computer-enabled social contact. This deepens engagement by enabling connection and support through peer tutoring. It may be achieved by planning for and allowing face-to-face communication among the students, which enables fast, adaptive, and responsive social querying when needed. By extending the cognitive resources available to solve a challenge from a single brain system to many (including sensory and motor systems, i.e., embodied cognition), the challenge can be solved more efficiently than the single brain alone (Foglia & Wilson, 2013).

This principle is about the importance of taking the power and utility of verbal peer communication into consideration for designing and implementing an LMS-mediated tutorial. Through verbal peer communication and interactions, students feel connected and supported. This can reduce student frustration when they encounter difficulties. Social interaction can also considerably deepen learning by allowing students' cognitive abilities to be socially guided and constructed through peer problem-solving, learning, and teaching (Vygotsky, 1978).

The provision for social interactions can be made possible by implementing the system in a group setting (computer laboratory) which enables spontaneous verbal peer communication since the students sit next to each other. This allows connection and support through peer tutoring and exchanging ideas or experiences, as well as developing and discussing new responses and giving feedback (Vrieling et al., 2019).

DP4: Provide multi-level, demand-driven resources

This principle specifies a learning model incorporating multi-level demand-driven resource provision rather than single-level resource provision. This deepens *affective* engagement by mediating different learning functions. It can be achieved by including picture big-picture items that provide awareness of the scope of the topic, precession items that offer details about specific sections of the topic, and reminder items that provide just-in-time information about technical aspects of completing an activity. Particular media types can support different learning strategies. This promotes active learning by preparing the students to retrieve and evaluate the information for various purposes (Kisicek & Lauc, 2015).

This principle supports easy access to appropriate resources and content review. To fit this purpose, resources must be short, topical, and focused to ease access and review of content. Different levels of resource provision should mediate different functions; for example, big picture items (e.g., pdf notes) provide awareness, and precession items (e.g., video clips) provide details. In addition, the design strategy of including examples of model answer items (e.g., hints on answer format) seemed to improve the accessibility of the system. Such easy-access resource provision enables the tutorial to be exploratory in character. It allows students to not only individualise their starting point depending on their prior knowledge and expertise but also to consolidate their knowledge as they fill their knowledge gaps (Kalyuga, 2005).

The provision for multi-level, demand-driven resource*s* can be enhanced by embedding resources within the activity, making them on hand all the time. This can be realised through an open-plan structure of activities to allow students to see and access resources as they work.

DP5: Consider LMS-assisted learning process regulation

This principle specifies a learning model that incorporates computer-assisted regulation of the learning process rather than self-regulation of the learning process. This deepens mathematical engagement by providing a useful space for "graceful failure" and safe recovery. It may be achieved by regulating the learning process through an LMS conditional release function. The conditional release function allows students temporary relief from a failure in order to enable them to try again and get better results (Fisher et al., 2014).

This principle is about providing space for graceful failure by identifying and acting on interim failures that therefore serve as opportunities for improvement. Imposing a temporary failure, when necessary, "can allow the student to re-examine content in an effort to achieve ultimate success" (Fisher et al., 2014, p. 229). Interim failure challenges students to pay attention to what they are doing and to note and rectify their errors.

This regulation of the learning process aims to give students a second chance to develop and refine their knowledge through adaptively rehearsing and exploring content. To achieve this objective, the LMS conditional release function can be used to lock progress until the pass mark is reached. This can be supported by accessible resources that foreground detailed precession (section 8.2.5(1)) and immediate feedback directing students to relevant areas in the resources. To enhance progress, the feedback may be improved by adding a response that is activated after a pre-determined number of interim failures (say 3), directing students to ask for assistance from the tutor (section 8.2.5(2)). This can help the tutor to identify and assist struggling students.

9.3.2 Methodology Principles (MP) for e-tutorial development

This study adopted the Educational Design Research approach of McKenney and Reeves (2018). As discussed in section 4.3, it followed an iterative and cyclical process, moving through three distinct phases, namely the Preliminary Phase (prepare for the experiment), the Intervention Phase (test and formatively evaluate in the classroom) and the Evaluation Phase (conduct and document retrospective analyses). It was also influenced by the inputs from Plomp (2013), Reeves et al. (2008) and Van den Akker et al. (2006). The researcher did modify the procedure, aligning with the recommendation of Ma and Harmon (2009, p. 90) that researchers examine their context and modify their model appropriately to suit their setting and user needs.

The following guiding principle is proposed for the researchers interested in conducting design-based research based on the retrospective analyses and comparison of the planned and actual conduct of the study.

MP1: Shorten the iterations

The iterative nature of design research can be long and tiring. To reduce the effect of this challenge, some stages of the iterations can be shortened to produce quicker work cycles. For example, in this study, due to its agile and iterative approaches, the Successive Approximation Model (SAM) (Allen & Sites, 2012) was followed in the tutorial development process as an alternative model for ADDIE. The five ADDIE stages were reduced to three: test, evaluate, and review (section 5.1). This facilitated the decision process and the transitions from cycle to cycle (sections 6.1.7, 6.2.8 and 6.3.7). Shortening the iterations resulted in obtaining a usable product more quickly due to quicker work cycles. This study demonstrated that using SAM in design-based research is a suitable methodology for short-term projects (such a PhD study).

9.3.3 Construction Principles for an LMS-mediated Tutorial System

Design products can also be significant research outputs (Herrington et al., 2007). In this study, the product is a design artefact in the form of the an e-tutorial system developed by the researcher. Among the most noteworthy contributions of this study were two construction principles for an LMS-mediated tutorial design.

CP1: Design the orientation section items of the e-tutorial as activities

This principle proposes turning the orientation section items (introduction and objectives) of the e-tutorial into activities in order to *motivate*/stimulate the process of actively reviewing and processing information contained in these items. This can be achieved by adding short quizzes to test reading and comprehension.

The orientation section of a tutorial is essential as it gives students an overview and an idea of what they need to do in the tutorial. It is typically made of static text information in the form of; an introduction to present an overview of the tutorial and how to access the activities and objectives to present an overview of the tutorial topics. However, in this study, it was observed that students were not interested in working through the Introduction and Objectives items of the e-tutorial. Therefore, there was a need to make the introduction and objectives items of the e-tutorial a challenge by adding short quizzes to motivate the students to read with comprehension.

CP2: Use the LMS test tool to construct the e-tutorial activities

This principle proposes using the LMS to seamlessly facilitate learning administration, i.e., content delivery, assessment delivery, and communication of results. This can be achieved by using the test tool to generate the e-tutorial structure and activities.

Embedding the Quizlets and resources side-by-side in the instruction section of the test tool can create a test environment with an open-plan structure, enabling students to see and access resources as they do the activities. The test tool can also allow the use of the conditional release capability of the LMS (section 9.2.1) and allocating partial credit for activities using fill-in multiple blanks question types.

9.4 Limitations of the study

This study was conducted as a small-scale research project (section 4.3.1). It was limited to convenience sampling (Cohen et al., 2007), where the sample was used as a test-bed during the design and development of the e-tutorial in response to the main research question. Therefore, it was not possible to generalise the findings beyond the sample. This objective (i.e., generalising the results beyond the sample) requires further research.

9.5 Recommendations for Further Research

The study is a starting point for more in-depth research in active learning and student-centred approaches by identifying areas that need further research. The findings suggest that an LMS-mediated tutorial is a practical possibility for effective deep student engagement in an online environment. Therefore, this study encourages and supports using an LMS-mediated tutorial environment to explore and consolidate student learning knowledge. In that regard, the researcher believes this study has opened up the following areas for further research.

1) Evaluation and validation of e-tutorial
2) Application of design principles
3) Engaging, student-centred e-learning

9.5.1 Evaluation and Validation of e-Tutorial

Any instructional material's design and creation are influenced by the intended audience, the subject matter, and the institution's organisational culture. As a result, it is possible that this study's findings may not have a universal value. However, these findings highlight some pedagogical, technological, social and contextual attributes that must be considered when designing LMS-mediated tutorials. Additionally, it provides guidelines for how to conduct design-based research in e-learning. However, given the limitations discussed in section 8.4, the e-tutorial needs to be further evaluated through summative evaluation with a larger group of students to assess and validate its effectiveness (Oh & Reeves, 2013; Wang, 2013) and to improve on the design of the system. Further research is recommended to verify the current study's findings to strengthen its contribution to the development of e-learning.

9.5.2 Application of Design Principles

The study contributes to modifying and strengthening theories that focus on perceptions regarding the nature of students and learning in LMS-supported environments. This study suggests mechanisms that should be considered in designing to implement engaging, student-centred e-learning in an LMS environment. This may help lecturers improve their teaching methods (for example, adding weekly LMS-mediated tutorials). For instance, many first-year students are under-prepared for higher education; thus, innovative learning intervention strategies are needed to succeed. Can LMS-mediated tutorials assist these students in bridging the gap? Further research is necessary to determine the solution to this query question.

9.5.3 Engaging, Student-centred e-Learning

Inspection of the results in chapters 6 and 7 indicates that, despite some challenges, students solved basic trigonometry tutorial questions, using a strategy of sketches and rough work to interpret information, solve the problem and then input the answers into the system. This suggests that the e-tutorial can help students to relate positively to engaging, student-centred e-learning, which may motivate them to improve their performance. From these results, the researcher recommends the following for further research.

1) This study does not cover external factors which may influence the implementation of LMS-mediated tutorials. Practical ways to overcome these problems should also be investigated.

2) The influence of LMS-mediated tutorials on student engagement for high, average and low achievers.

3) How these principles may be generalisable to other subjects (not just basic trigonometry or foundational mathematics). For example, does preparing responses on paper first apply appropriately to other content areas?

9.6 Concluding Remarks

This study arose from the realisation that one of the profound challenges for modern higher education lecturers was how to harness the complex array of technology tools on offer in the quest to provide learning environments reflective of diverse student needs, backgrounds and learning preferences. This study focused on and explored an LMS as an example of such an environment in higher education. In this context, the quality of student engagement was considered paramount in the design and structure of learning objects offered to students in an LMS environment.

Findings were in the form of transformations of the e-tutorial system as it was developed. Among the most noteworthy contributory modifications were changing from 1) “read first, then do” to “do first, read when necessary”, 2) “work on the computer” to “work on paper then capture on the computer”, 3) “physically separated work with computer-enabled social contact”, to "individual computer work in face-to-face social settings.” 4) “single-level of resource provision” to “multi-level, demand-driven resource provision” and 5) “self-regulated” learning process regulation to “computer-assisted” learning process regulation. The discussion of these findings indicated that to enable students’ deep and effective engagement in the process of learning fundamental trigonometry within an LMS-mediated tutorial, one needs to design the system with some activities that can create a demand for knowledge, encourage rough work (writing) and face-to-face social interaction, supported by multi-level, demand-driven resources, and computer-assisted learning-process regulation. Contributions to research by this study were in the form of 1) Design Principles for LMS-mediated tutorials, 2) Principles for an e-tutorial development methodology, and 3) The LMS-mediated tutorial system.

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11 APPENDICES

Appendix 1: System Design-Develop

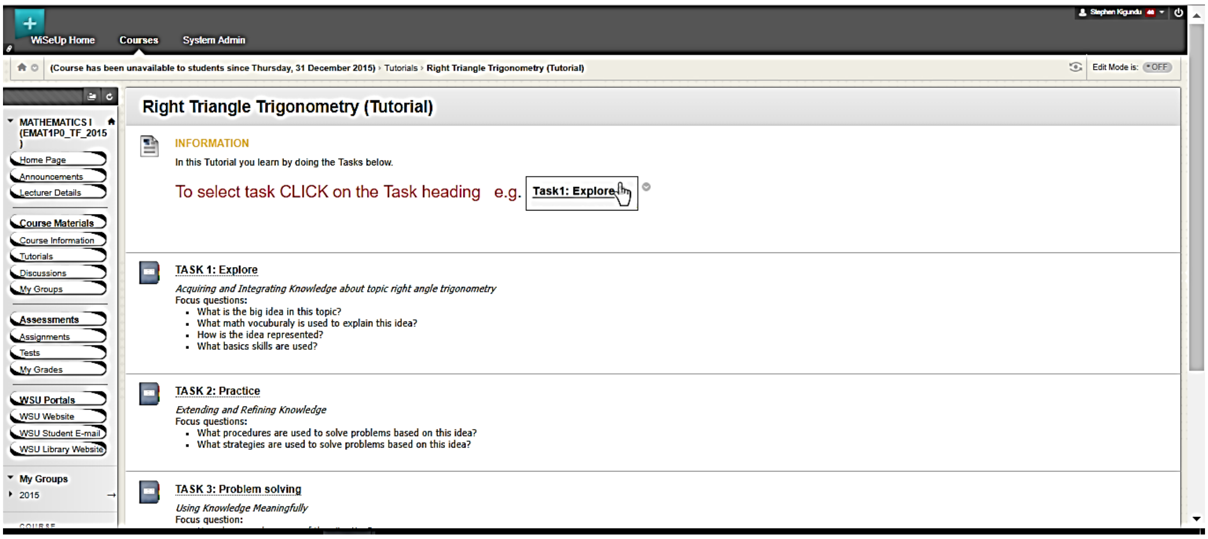
1.1 Use of Learning Management System

The purpose of the LMS was to facilitate the learning processes through presentation of 1) instructions, 2) educational content and 3) activities/tests.

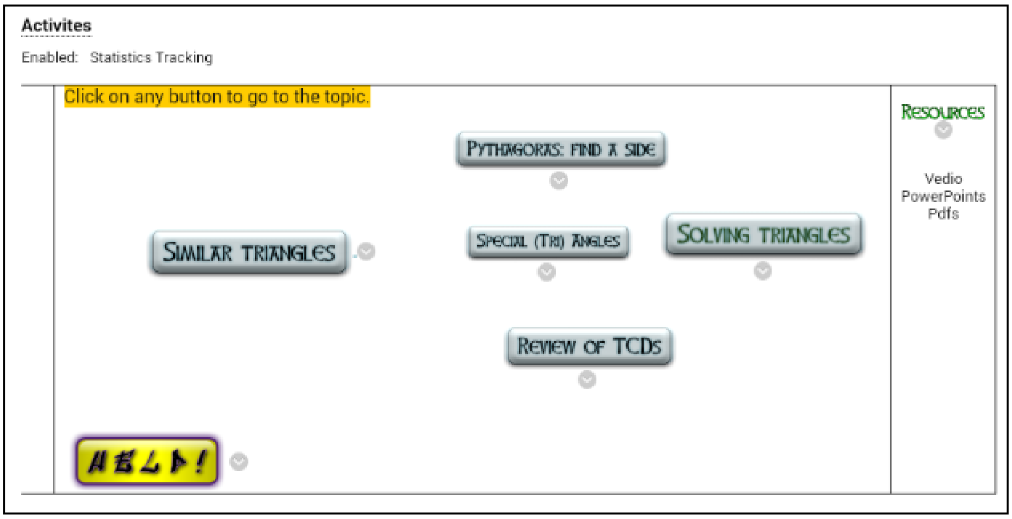
LMS Task analysis

Object	Engage in learning process			
Actions	Open e-Tutorial page	Review page content	Review resources	Do activity
Operations	click on navigation link	read	play media	fill in blanks

Set up of Tasks in LMS



c. Set up of Activities in Task 1



1.2 Tasks Overview

The tutorial design was driven by tasks as articulated below.

Task1: Explore

The purpose of this task was to support students to acquire:

1) Conceptual knowledge of overarching ideas and facts which are foundational for understanding of right triangle trigonometry,

2) Mathematics language or vocabulary, terminology and phrases which are necessary for participation in discussions about the topic,

3) Procedures/skills to effectively and efficiently apply the mathematical concepts studied.

This task consisted of 4 items, 1 Introduction, 2 Objectives, 3 Activities, and 4 Evaluations.

Introduction

The purpose of this item was to enable students to 1) have an overview of the Task and 2) have an idea of what they need to do within this task.

Introduction Task analysis

Object	Engage in learning process: Acquire knowledge about nature of task		
Actions	Open page	Review introduction	
Operations	click on navigation link	read	

Objectives

The purpose of this item was to 1) present content of the Topic, 2) enable students to evaluate what they know or want to learn about the topic by filling in the KWL survey and 3) decide which activity to do next.

Objectives Task analysis

Object	Acquire and Integrate Knowledge		
Actions	Review objectives	Complete KWL	Determine what to learn?
Operations	open page	Fill in multiple blanks (typing)	Decide Activity to do in Item3

Item3: LMS Activities

The purpose of this item was to enable students to 1) learn through review of content presented in multimedia resources and 2) Assess understanding by completing the accompanying test.

Activities Task analysis

Object	Acquire and Integrate Knowledge		
Action	Review content in multimedia resources	Complete activity	Assess understanding
Operation	Play video/ppt	Fill in multiple blanks (typing) Click submit	Check feedback

Task2: Practice

The purpose of task was to support students to acquire:

1) Conceptual understanding of overarching ideas and facts that are foundational for solving of right triangle trigonometry problems,

2) Strategies and approaches (how to) for solving of right triangle trigonometry problems,

3) Skills and procedures that help in solving problems fluently and efficiently.

Task2 Task analysis

Object	Acquire and Integrate, strategies and skills for solving right triangles		
Actions	Use strategy e.g. Write equation	Substitute in equation	Solve equation

Operations	Determine strategy	Match given information with equation variables	Use algebra to simplify

Task3: Problem solving

Using Knowledge Meaningfully

The purpose of task was to support students to use acquired knowledge meaningfully through application of:

1) overarching ideas and facts that are foundational for solving of right triangle trigonometry problems,

2) strategies and approaches to solving of right triangle trigonometry problems,

3) skills and procedures that help in solving problems fluently and efficiently.

Task3 Task analysis

Object	Use acquired knowledge, strategies and skills to solving right triangles		
Actions	Use strategy e.g. Write equation	Substitute in equation	Solve equation
Operations	Determine strategy	Match given information with equation variables	Use algebra to simplify

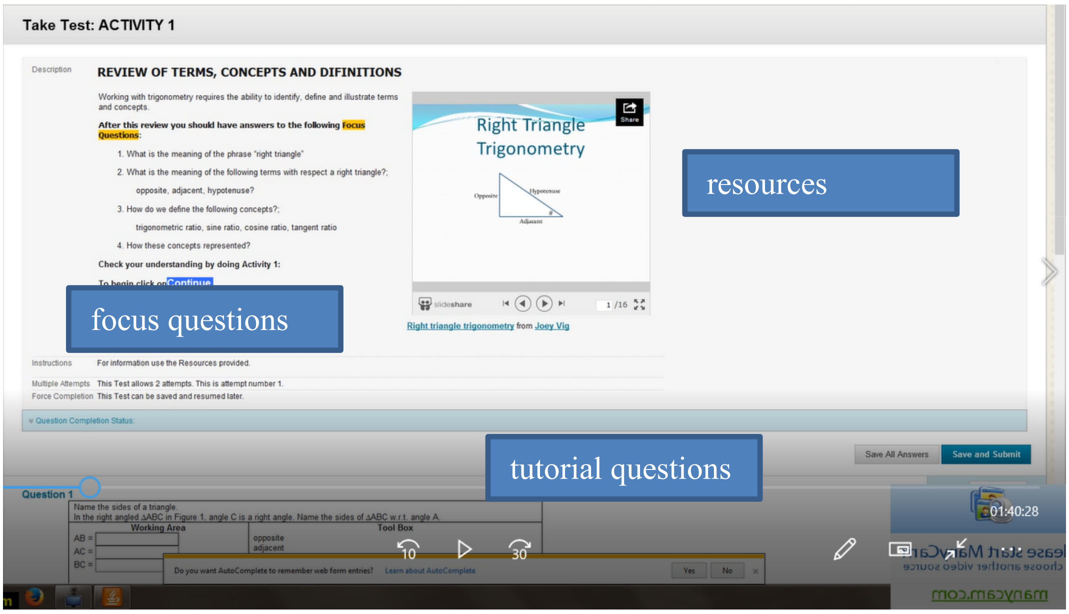
1.3 Activities Structure

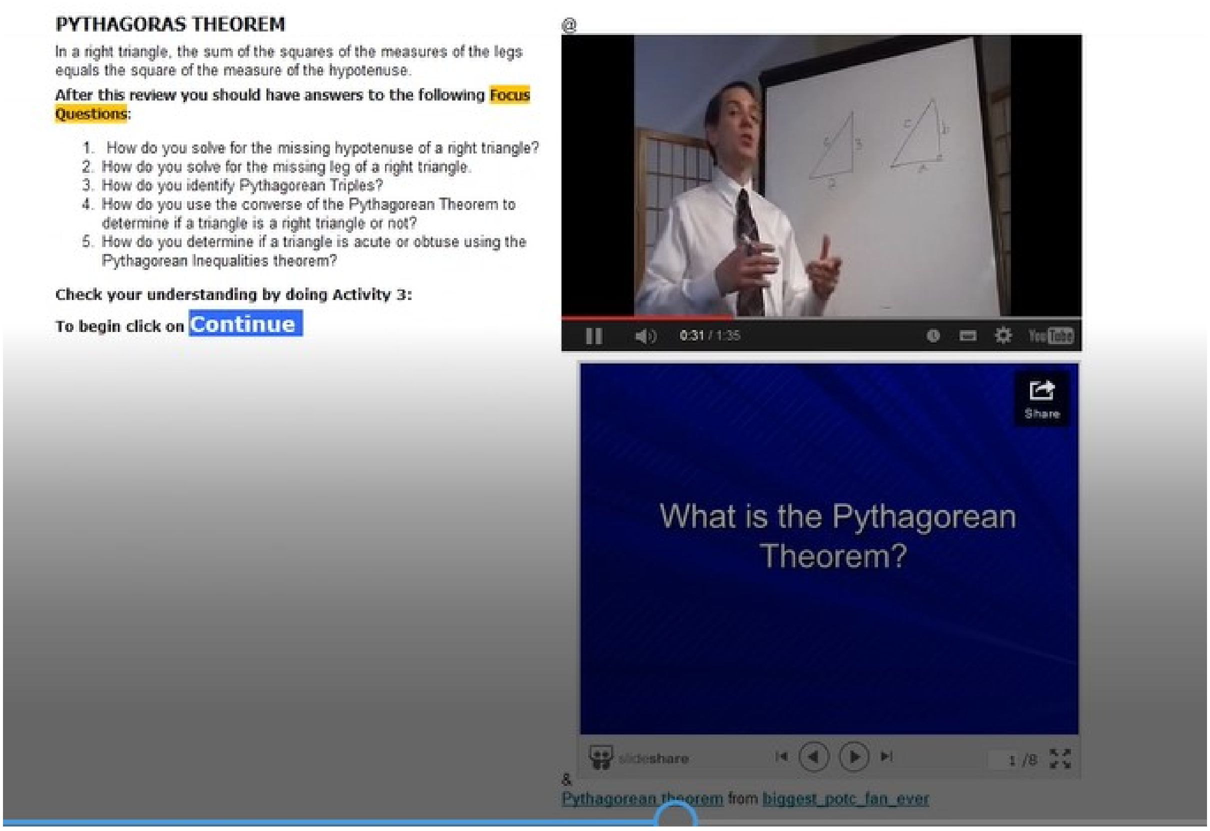
a) Cycle 1

Activities had three parts, focus questions, resources and tutorial questions.

Resources were in the form of YouTube videos, SlideShare presentations and pdf notes.

Tutorial questions were in the form of fill blanks and short answer marked by tutor.





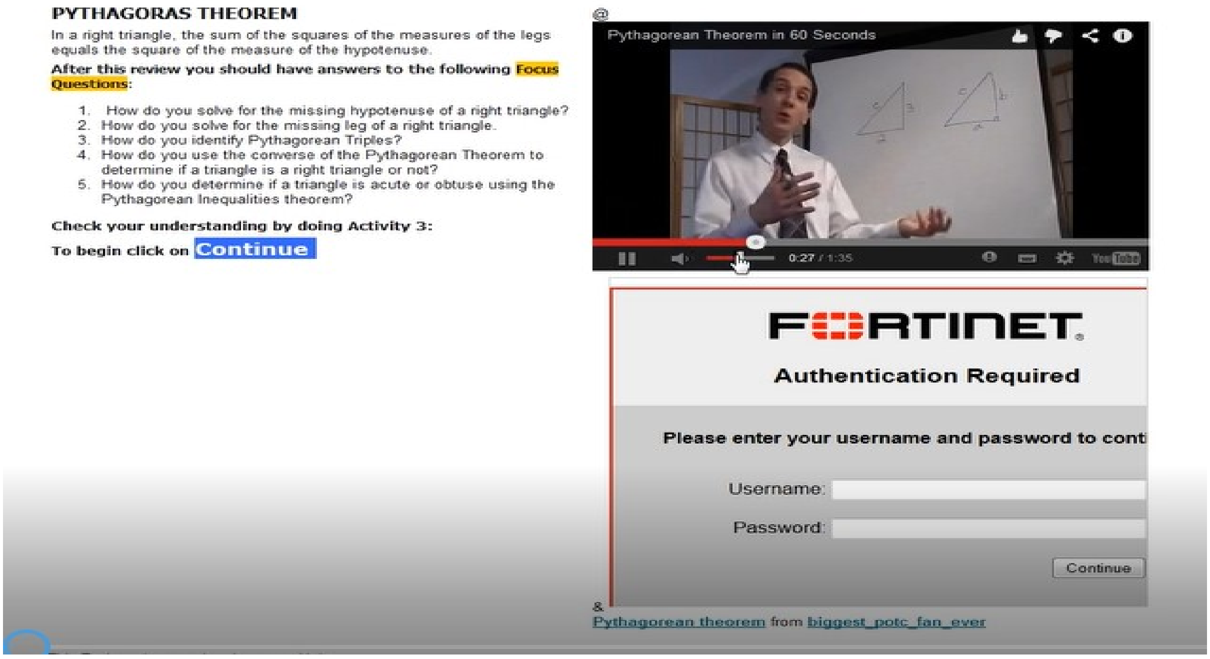


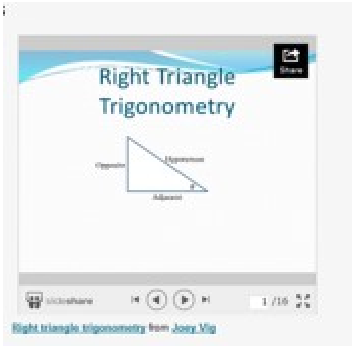
Figure 11.1: Tut 1 Activity structure

b) Cycle 2

Activities had three parts resources Quizlet and resources followed by tutorial questions.

Resources were in the form of flush presentations and pdf notes.

Tutorial questions were in the form of fill blanks and short answer marked by tutor.



Quizlet

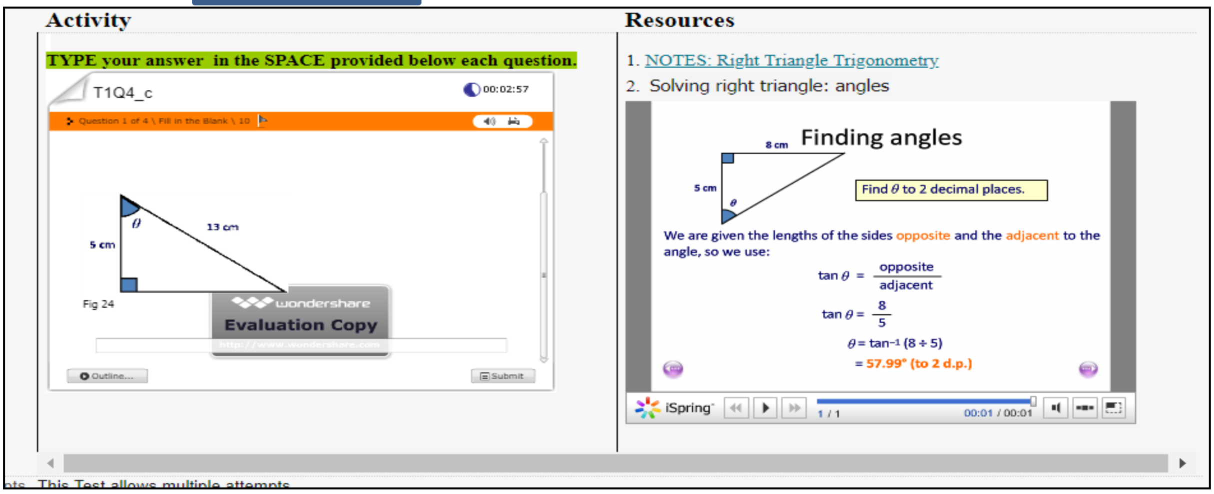


Figure 11.2: Tut 2 Activity structure: Introduction of Quizlet.

c) Cycle 3

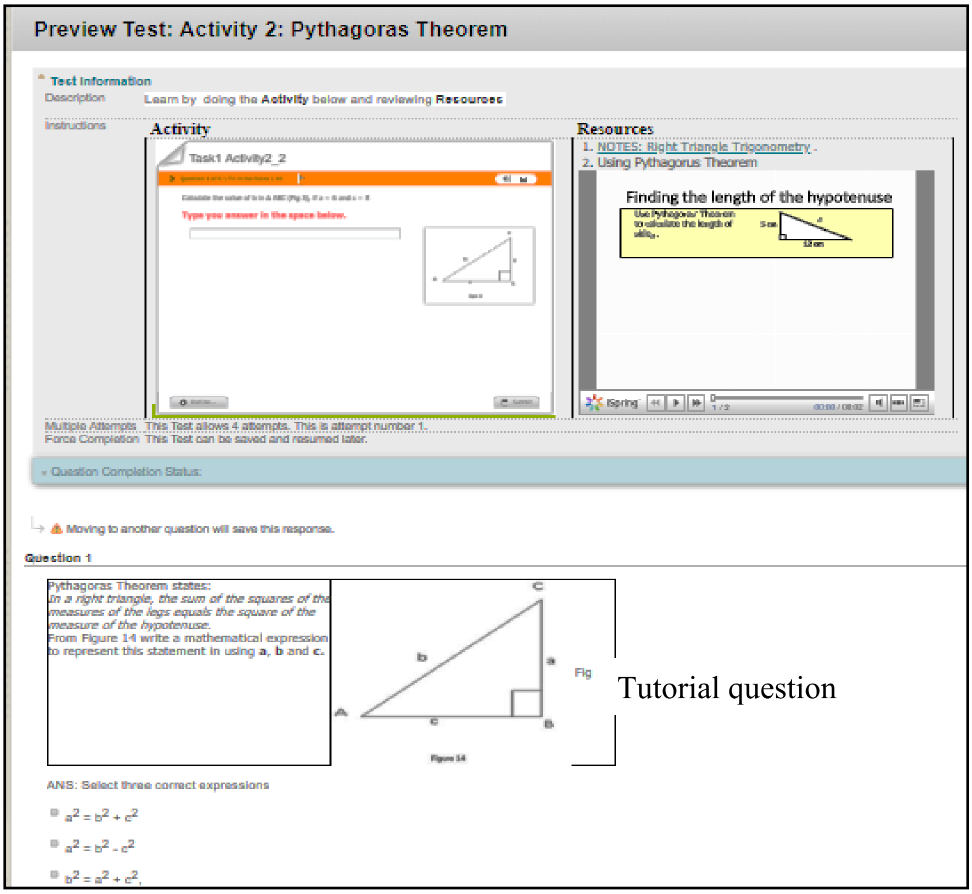
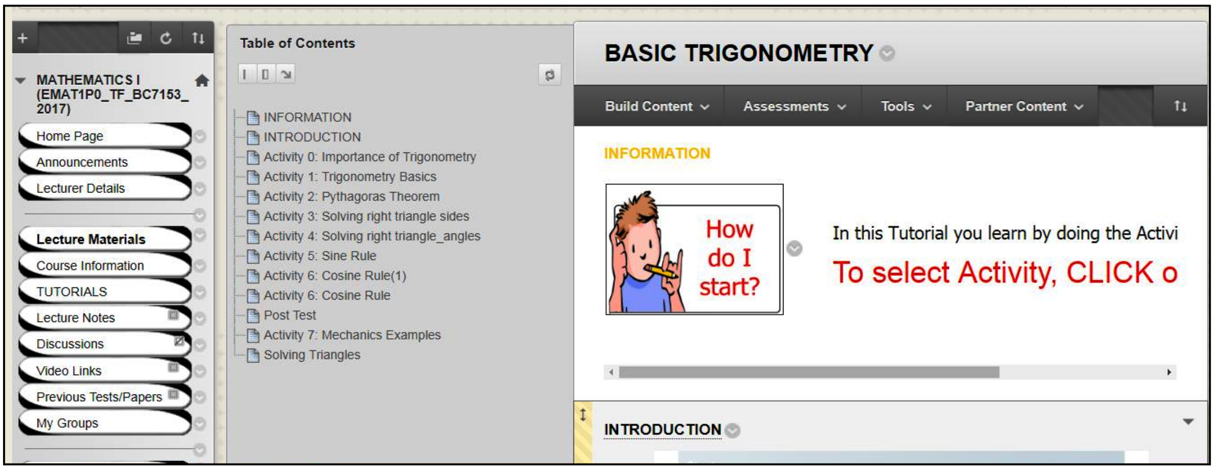
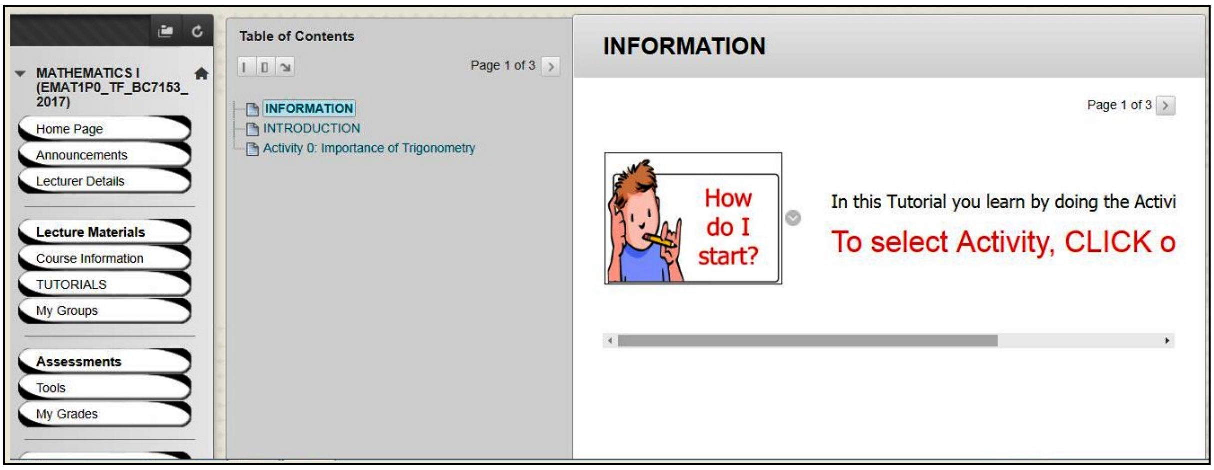


Figure 11.3: Tut 3 Activity structure

d) Cycle 3 Navigation structure



e) Cycle 3 Conditional release



1.5 Introduction and Objectives

a. Cycle 1

Introduction

SOLVING RIGHT TRIANGLES

To solve a right triangle means to find the measures of all its sides and angles

What key terms, concepts and basic skills do you need to know in order to solve right triangles?

To answer this question, do the following:

1. Objectives
Read through the objectives and do the KWL Survey

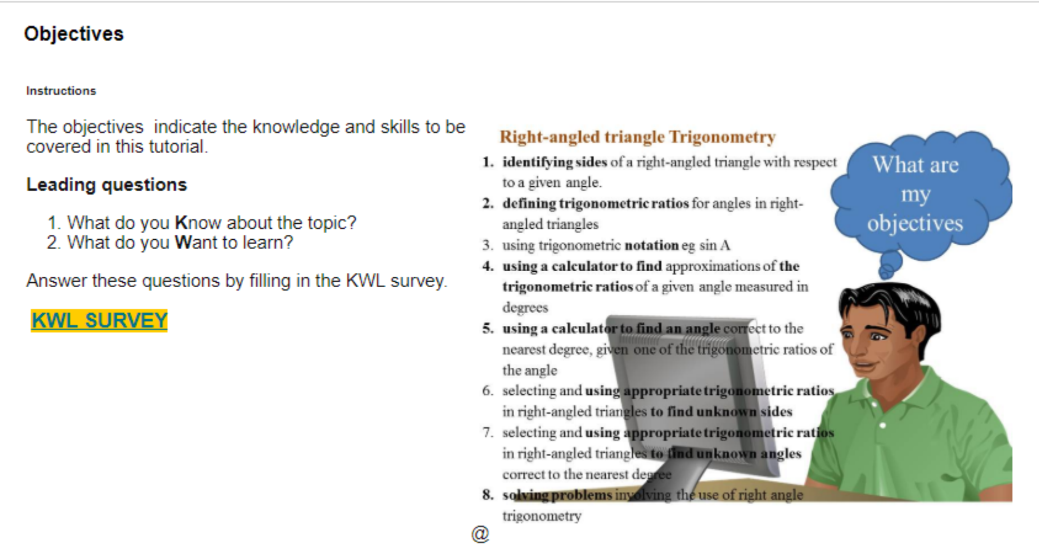
2. Activities
Use the supplied resources as sources of information and ideas, together with your own experience to identify and list what you think are the key terms, concepts and basic skills used to solve right triangles.
Test your understanding by doing the accompanying activities.

3. Assignment
Answer focus question by creating a summary of (in your own view) key terms concepts and basic skills used to solve right triangles.
Present the information in an organised way using a graphic organizer of your choice.

4. Evaluation
In order to assess whether the work done make sense do the following:

- **Peer evaluation**: to evaluate your classmates' performance in the given assignment for the purpose of giving feedback and improving learning. Use the given rubric.
- **Self-evaluation:** answer the questions in the Learning Journal to help you to think about, reflect on and evaluate your own learning.

@



b. Cycle 2

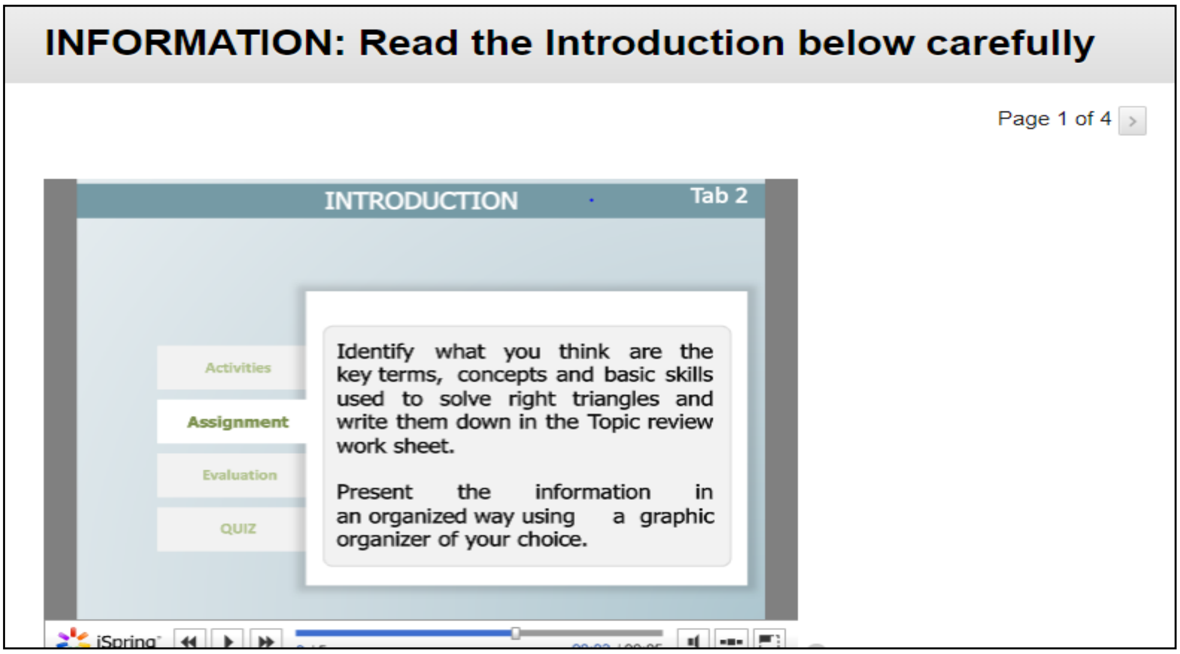


Figure 11.4 : Introduction; interactive presentation

c. Cycle 3

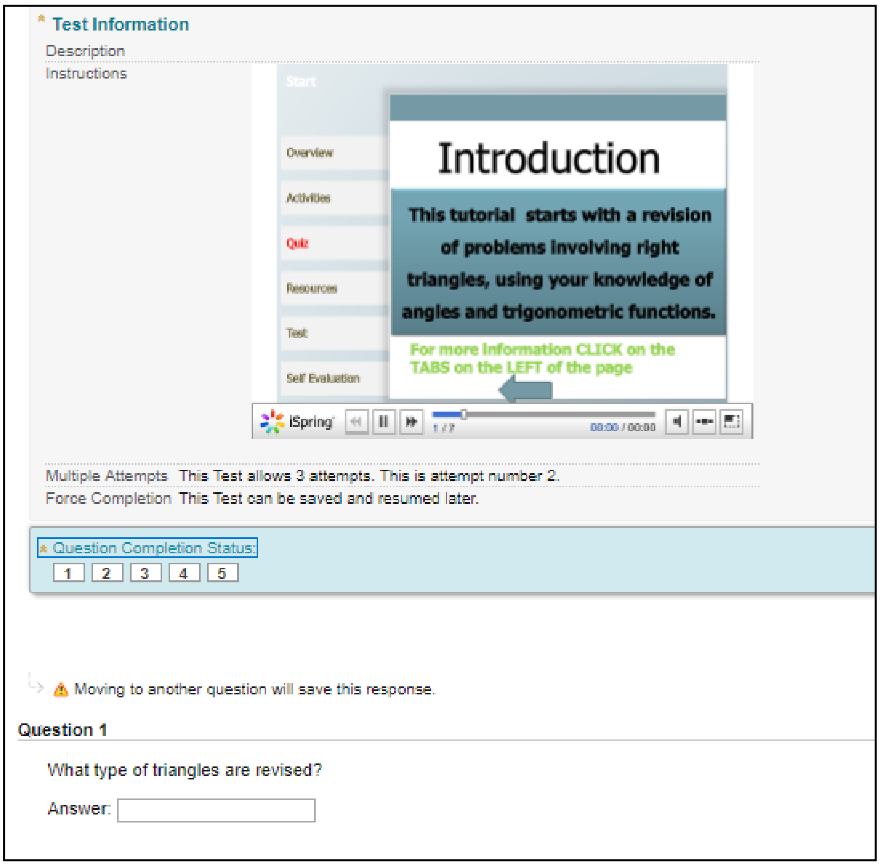
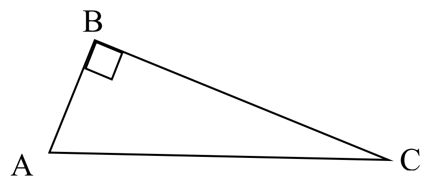


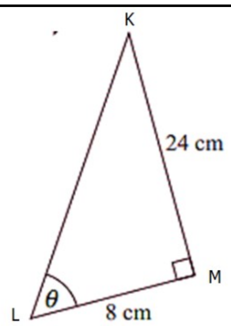
Figure 11.5: Introduction: interactive presentation and test

1.4 Examples of Tutorial questions

a. Fill in multiple blanks tutorial question

In triangle ABC, Figure 15; AB = x , AC = 11, BC = 40 1.1 Solve for x 1.2 In Figure, AC = 117 and BC = 40, use **trigonometry** to show that angle A = 20^{O} Working Area 1.1 Given AC is the [a], BC is [b] and the missing side x is the [c] We can use the [d] ratio to solve for x Therefore [1] [2] [3] [4] Or we can use the [e] ratio Therefore [5] [6] [7] [8] 1.2 We can use the [9] ratio to solve for angle A Therefore [10] [11] [12]	 Figure 15 Tool Box tan opposite adjacent x = 117*sin70 ^{O} hypotenuse sin tan70 ^{O} = x/40 cos sinC = AB/AC cosC = BC/AC cos70 ^{O} = 40/117 tanC = AB/BC sin sin70 = x/117 x = 40*tan70 ^{O} x = 109.9

b. Example of open response task

5. Calculate the value of KL in Δ KLM (Fig 22), if LM = 8 and KM = 24 Show all your working and write your answer correct to 1 decimal place.	

1.6 Feedback

a. System Feedback

Two types of feedback were afforded by system at the end of each activity; correct or incorrect answers and attempt score (mark obtained).

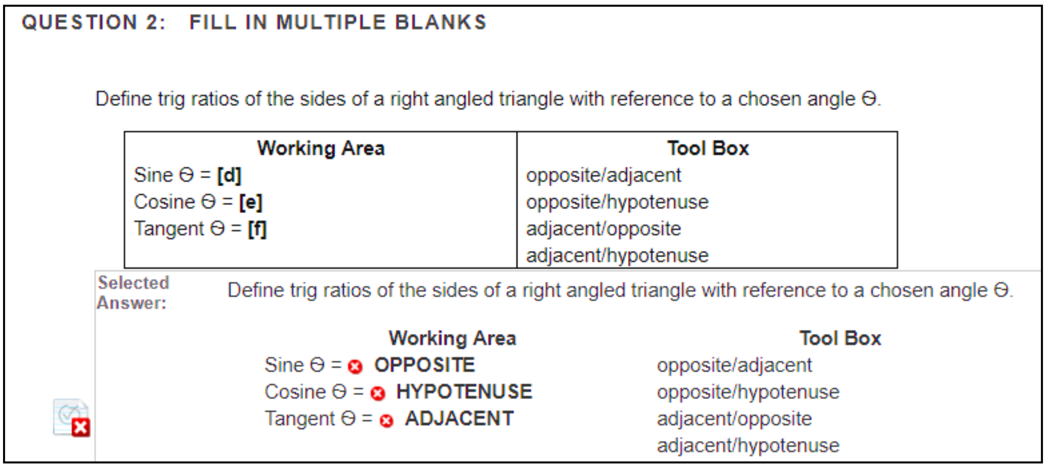


Figure 11.6 : Correct or incorrect answers

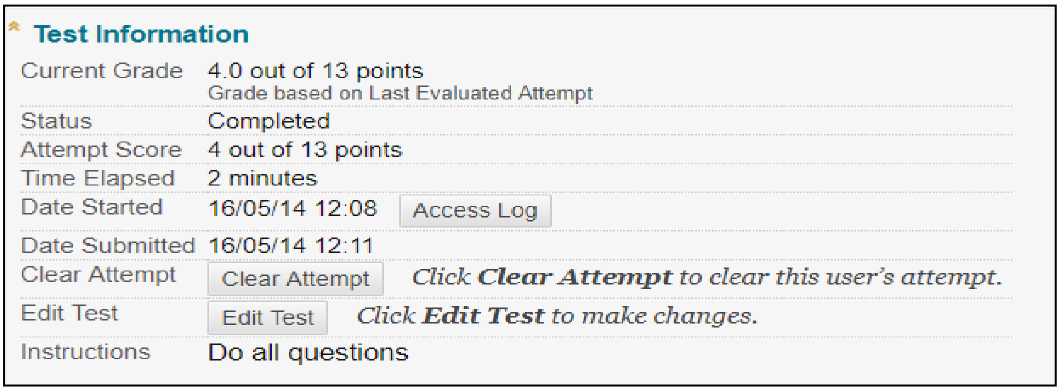
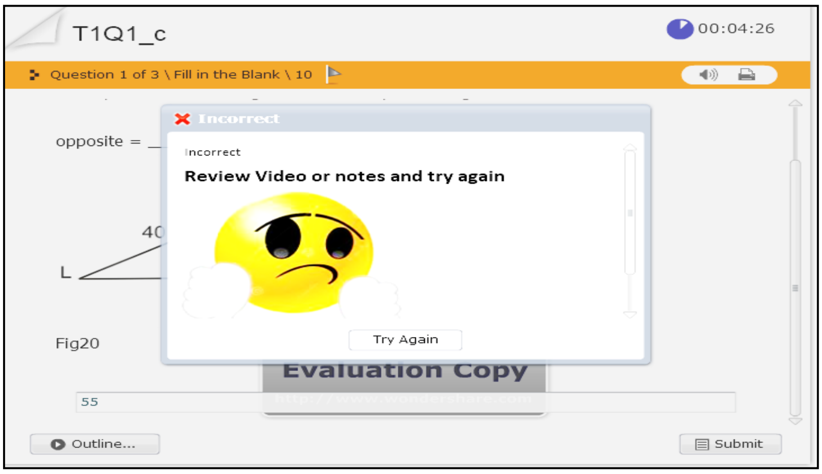
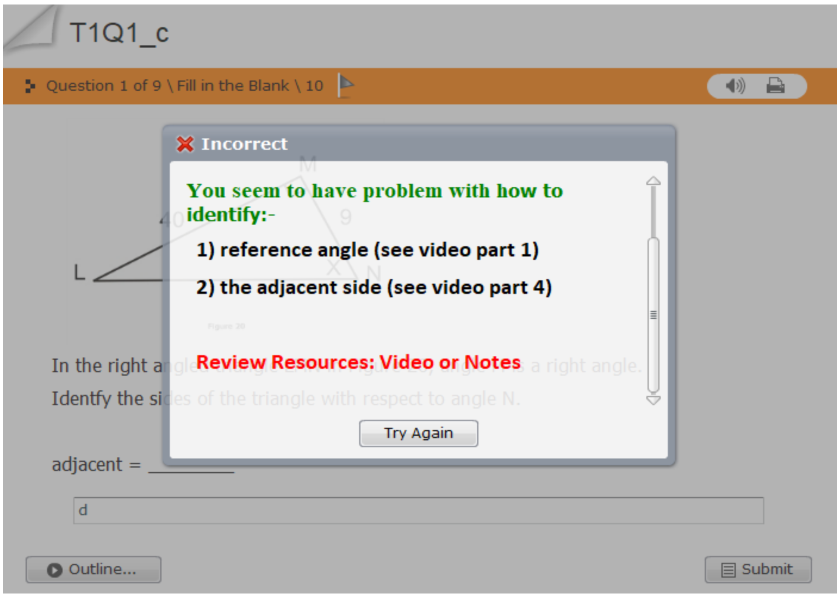


Figure 11.7: Attempt Score (mark obtained)

b. Quizlet Feedback (cycle 2)



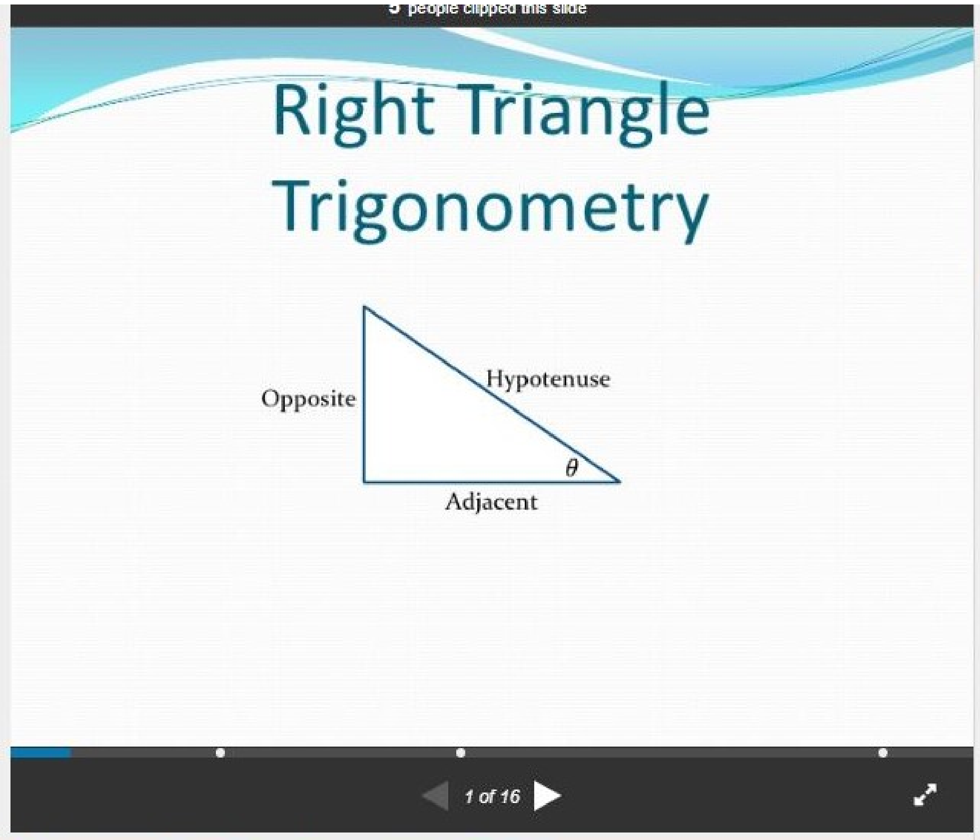
c. b. Quizlet Feedback (cycle 3)



Appendix 2: Resources

2.1 Phase 1

b) Example of SlideShare presentation,



c) Example of pdf notes

Notes for Trigonometry

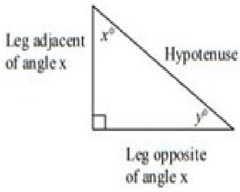
Trig Functions:
Sine Cosine Tangent

All Trig functions are used for right triangles only. Each one is a proportion and when working the problem should be cross multiplied and solved.

Sine $x^{\circ} = \dfrac{\textit{length leg opposite of angle}}{\textit{length of hypotenuse}}$

Cosine $x^{\circ} = \dfrac{\textit{length of leg adjacent of angle}}{\textit{length of hypotenuse}}$

Tangent $x^{\circ} = \dfrac{\textit{length of leg opposite of angle}}{\textit{length of leg adjacent of angle}}$



If you use a different angle, then the adjacent and opposite legs reverse. You never use the right angle for trig and the hypotenuse never changes position.

Mnemonic for remember the trig functions

SOHCAHTOA

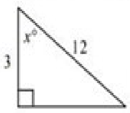
S-Sine
O-Opposite leg
H-Hypotenuse
C-Cosine
A-Adjacent leg
H-Hypotenuse
T-Tangent
O-Opposite leg
A-Adjacent leg

$$\text{Sin } x^{\circ} = \frac{\textit{Opposite leg}}{\textit{Hypotenuse}}$$
$$\text{Cos } x^{\circ} = \frac{\textit{Adjacent leg}}{\textit{Hypotenuse}}$$
$$\text{Tan } x^{\circ} = \frac{\textit{Opposite leg}}{\textit{Adjacent leg}}$$

Since Trig is done with angles and angles are measured in degrees, then the calculator set in the right mode. If the calculator is not set to degree mode, then every answer will be wrong. Calculators have 3 modes; grad, rad, and deg. The deg mode is the degree mode. In TI graphing calculators the mode is found using the mode key, and the second line you will find the deg. Select it by using the equals(enter) key. If you have a different calculator, then consult the manual or ask a math teacher to help you. Each calculator can be different, so it is always good to know how your calculator works.

There are two types of trig problems. One you find the missing side, the other your find the missing angle. Each one is worked a different way, so look at the examples carefully.

Example 1 Find the missing angle



Because the hypotenuse and side adjacent to the angle is given, the trig function using those pieces is cosine. This allows us to set up the following equation. Though it looks like a proportion, do not solve it like a proportion.

$\cos x^{\circ} = \dfrac{3}{12}$

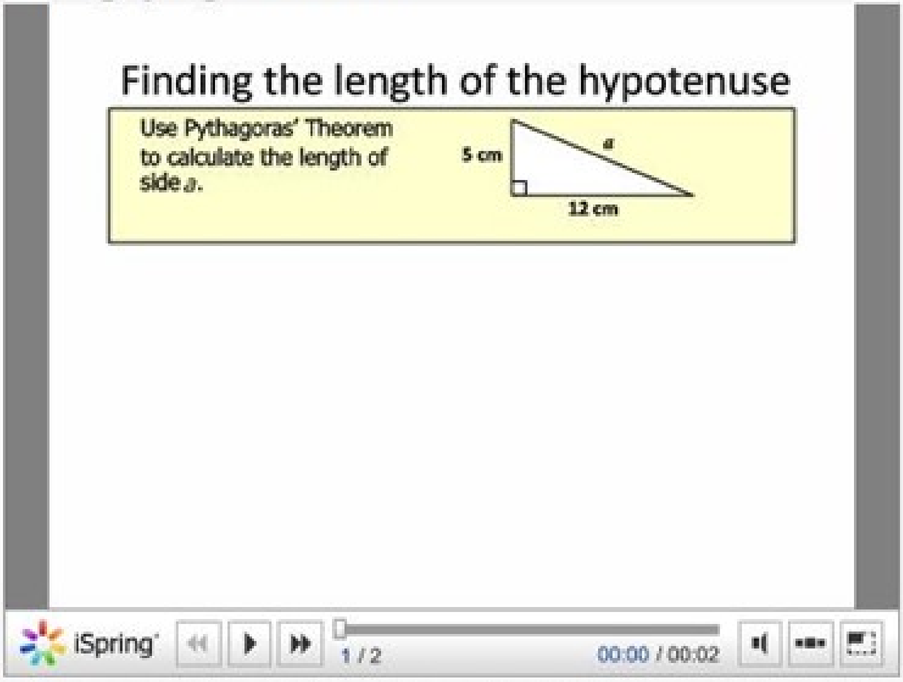
To solve this find $\cos^{-1}$, then type in fraction$(3/12)$. Hit enter, since answer is an angle round to nearest degree. $x = 76^{\circ}$

2.2 Phase 2

a) Interactive Flash video

Resources

1. NOTES: Right Triangle Trigonometry .
2. Using Pythagorus Theorem



Appendix 3: In Class Observations

3.1 Cycle 1

S1 Started with doing rough work on paper, abbreviations, eg sin, not catered for

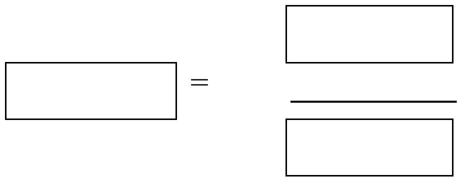
S2 Wrong answer. Did not use notes , used knowledge (*why*) I thought I know this

S3 Using computer, "have to write down then copy to computer"

S4 Using computer, "where are the signs like multiplication, addition"

S5 Correcting mistakes, student made typing mistake when copying from paper to computer

S6 Question not clear , Task 1, Activity 3 puzzling ("at least give one of the three")



S7 Using computer, how to fill the missing spaces

S8 Using computer, how to complete activity

S9 Using computer, how to complete or fill the missing spaces

S10 Using computer, how to put in an inverse or tan, sin, or cos

S11 System answer seem to be wrong. student frustrated after getting it wrong three times. (student's comment, "the computer makes me stupid").

3.2 Cycle 2

S1 asked for assistance with the Introduction presented on opening Task1 (student shown how to navigate presentation); after the tutor's help, the student successfully clicked on Tabs to go to another page/section of the presentation, however, this student spent a very short time on the Introduction (approximately 1min).

S2 YouTube link presented a connectivity error message

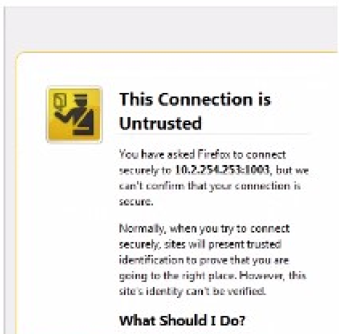
S3 Quizlet answers seemed to be wrong, questions were not clear

S4 Twelve (12) students asked for assistance with Quizlet questions; all of these students had worked out the questions on paper (assisted on how to copy/enter answers to the computer).

S5 did Activity1 Quizlet three times; student comment "did not use video" (why) "confusing and too long" "has no sound" (student shown how to play the video; pause, rewind, or skip); Quizlet was a little confusing, did not know how to start it. (YouTube link sometimes presented a connectivity error message)

S6 did Activity1 Quizlet two times; student comment, “I watched the video and read the notes, how do I do Quizlet again” (student shown how to re-do Quizlet) (YouTube link sometimes presented a connectivity error message)
S7 Quizlet answers seemed to be wrong (why?)
S8 asked for assistance with tutorial questions, (assisted on how to enter answers in the computer)
S9 worked out the tutorial questions on paper and then copied them to the computer. (assisted on how to enter answers in the computer)
S1 needed to be shown how to click on Tabs to go to another page/section of the presentation
S5 asked for assistance on how to play the video (how to look for information)
S1 found Quizlet a little confusing (how to start)
S4 did not know how to start Quizlet.
S6 could not figure out how to repeat Quizlet (after failing).
S7 noted that Quizlet answers seemed to be wrong, questions were not clear
S1 worked out the tutorial questions on paper and then copied them to the computer (assisted on how to correct mistakes when entering answers on computer)
S8 using computer, worked out the tutorial questions on paper (assisted on how to correct mistakes on computer)
S9 worked out the tutorial questions on paper (assisted on how to correct mistakes on computer)
S10 using computer, tutorial questions, Copy and paste from Tool Box not smooth (assisted on entering answers on computer)) (YouTube link sometimes presented a connectivity error message)
S11 worked out the tutorial questions on paper; how to correct mistakes when answering tutorial questions on computer
S12 worked out the tutorial questions on paper; needed assistance with how to correct mistakes on computer.

In some cases, the resource link showed a connectivity error message that the source can be trusted.



Right triangle trigonometry from Joey Vig

3.3 Cycle 3

S1 asked for assistance with Introduction

S2 asked for assistance with Introduction

S3 asked for assistance with Introduction

S4 asked for assistance with Introduction

S5 asked for assistance with Introduction

S6 asked for assistance with Introduction

S7 asked for assistance with Introduction,

(students shown how to navigate presentation)

S1 explored resources before doing Quizlet questions; requested assistance with accessing and reviewing resources. (S1 one was a novice computer user, shown how to play the videos and scroll the rough work pdf notes)

S4 rough work of tutorial questions, disappointed with the results (marks) and wanted to know where they went wrong

S6 rough work of tutorial questions, disappointed with the results (marks) and wanted to know where they went wrong

S7 rough work of tutorial questions, disappointed with the results (marks) and wanted to know where they went wrong

S8rough work of tutorial questions ; how to input results into the system.

S9 rough work of tutorial questions how to input results into the system.

S10 rough work of tutorial questions how to input results into the system.

S11, S12, S13, S14, decided to work in groups; talking to each other, low voice levels. (reason, “we want to ace the activities”) (4 groups were identified)

S11 disappointed with the results (marks) and wanted to know where they went wrong

S14 rough work of tutorial questions, disappointed with the results (marks) and wanted to know where they went wrong

S15 explored resources after experiencing challenges answering Quizlet questions; requested assistance with accessing and reviewing resources. ((S15 arrived late after the orientation session, student shown how to play the videos and scroll the pdf notes)),

S15, rough work to do Quizlet calculations; asked for assistance on how to input results into the system (students were shown how to type answers in the system)

(Students automatically (are kin to) checked results (marks) and where they went wrong)

(2 students found looking at other websites)

3.4 Cycle 4

Two tutors were recruited to assist in the class and to note nature of requests for assistance.

24 February

1. How to find a side using a cosine rule
2. How to use a computer calculator
3. How to punch an inverse or tan, sin, or cos
4. Struggling to resume answering the missing question
5. How to insert the signs like multiplication, addition etc
6. How to open WiSeUp
7. How to use calculator in computer
8. How to open active presenter
9. How to view marks after activity
10. How to go to next activity
11. How to find trig ratio using a computer calculator
12. How to refresh a computer after activity
13. How to stop and refresh active presenter App
14. How to identify adjacent angle on a right-angled triangle
15. Activity 3 Q2 & 3
16. Struggling to correct to the nearest whole number
17. Struggling to correct to the two decimal places

03 March

1. How to use cosine rule
2. How to find an angle given three sides
3. How to find trig ratio of sine
4. How to change mode of the calculator in the computer
5. How to use a sine rule
6. How to find and use the calculator of the computer
7. How to find angle given two sides of the computer
8. How to identify the missing side
9. How to use cosine rule to find the unknown side or angle
10. How to stop and start active presenter

11. How to name the side of a triangle
12. How to use sine rule to find angle or side
13. How to answer a question that need to complete or fill the missing spaces

Appendix 4: Interview responses

4.1 Cycle 1 Interviw transcript

One session made up of five students

Do you regularly do tutorials?

Student1: "Yes our lecturers do provide us with tutorial classes with tutors to assist us."

Do you attend these tutorial sessions?

Student2: "Yes, we do attend, usually during the week. We attend our tutor, Cedric."

How would you compare the work that you do with Cedric with the work covered in this software?

Student3:" I find the tutorials from the software very exciting, because we do all the work in the computer and we find the tools necessary within the software. You can sit at home on your own and do these tutorials in your own spare time."

Student4:" I find this kind of tutorial very easy; you can also learn more how to use the computer."

Student5:" For a person who is computer illiterate, they will probably find it difficult because it is based on working on the computer. I personally find it exciting because it is very convenient and it is faster than having to do all the work manually."

Student1:" I find it very easy because we are using the computer and the software gives us guidelines to find whatever we are looking for and it gives us instructions on how to do our work."

Do you think you could have figured the software out without my assistance?

All Students: "No, absolutely not."

So in the beginning, you need somebody to take you through?

All Students: Yes.

If I would say to you, you must do task no.2 on your own. Do you think you can do it?

All Students:" Yes we can do it on our own because you have showed us how to login to the software and how to work using e-tools. We know how to find the tools."

Would you recommend to your lecturers that we continue with this software as a learning tool and put more content from your course? Because what you just did was just trigonometry and it was a sample of what the software will contain.
All Students: “Yes we would defiantly recommend it.”

What would you like me to put in the software considering you course, to help you for revision for your exams?
Student3: “You can put in differentiation in Maths not just trigonometry but other modules of Maths too. You can also put in other subjects like Mechanics. “
Student1: “I would like to see all work we have done in our course covered in this software. I would like to see the whole syllabus for this year i.e. Maths, Mechanics. “
If I put all the necessary work in the software. Where would you go for practising and doing the exercises covered in the software?
Student5: “We would access computers in the school library. But that would need for the school to install more computers in the library because there are only a few computers at the moment.”
Do you have any other comments?
Student2: “When using this software, you have to be computer literate. You need to have computer skills and know computer basics. If that is the case this software would be easy to use and you will get your work done faster.”
Do you, as Mechanic students, have a subject that covers computer basics?
All Students: “Yes we do have a subject called Computer skills.”
Does this subject give you enough knowledge to acquire the computer basics and computer skills?
All Students: “Not really, the subject doesn’t equip us with enough skills. We only do Microsoft word, excel, PowerPoint etc.”

4.2 Cycle 2 Interviw transcript

One session made up of five students

Session 1: Group of 2 weak students
What did you find problematic?

Student1: When I was answering the questions, I used abbreviations, when I looked at the answers required the full word, e.g. hypotenuse
Student2: I do not understand the questions sir. the questions were not clear. (*did you read these Notes?*) I did not use notes. (*why*) because I thought I know this.
Student1: I do read the notes but sometimes but my answers were wrong, I do not know what is wrong.
Student1: I could not see the following questions. Some of the questions were at the corner or at the bottom. In other computers, there no full questions. Sometime the answer (system) was wrong *(how did you know that it was wrong)* I checked many times.

Do you think the system can be useful?
Student1: Some of the students may have taken 1 or 2 years gap-year. So, WiSeUp helps these to revise. When lecturers is lecturing in the class, they do not go step by step. They take that you know these things. So WiSeUp we do revision, revision so that we can in class perfectly.
Student2:

Sometimes you took long doing one question.
Student2: I think it is the computer and sometimes you do not understand
Student1: Sometime, the reason why you take too much time when answering the question.. you have to wrote something down so that you know the angles where to put your answer. where , how can put it , you must wrote the full answer and then copy it to computer so that you know you writing the perfect thing.
Student2: I do not understand the question. I do not know what angle to use.

So, you see that there was this presentation, then you come here at see this question, was this (?) useful in answering this question?
For example, here it says that define trig ratio. Which part of the presentation can you use?

Student1: it is confusing I do not know which part to do

Student2

When you finished the Activity, you remember you got your marks and the answers. now were the answers, did you understand where you go wrong?

Student2: yes but sometimes I do not understand…just because.. I know…. I don't know how to put it …for example there is a right triangle then they say we find the side…then I use the side that was given… whatever... then I find the side but when I see the answer that I wrote is not the same as they are writing…..then you don't know what was problem because this is the computer and I am using the brain.

Student1: you must tell us to put to 2 decimal places or three significant figures like that…. because sometimes you find that the answer is 8.7 but weena you said 8.1 … but you see no difference in the answers….. you check here

Student2: We usually know that if they didn't say …. we must put it in three decimal places

but look here it is says here to one decimal place… so it must put in the…

Students1&2 in the statement, yes in the statement.

4.3 Cycle 3 Interview transcript

Two sessions made up of total of eight students

Session 1: Group of 3 weak students

What challenges did you encounter?

Student1. I solve problem but it is difficult to punch in computer, did not finish test

Student2. No good in using computer

Activity 1?

Student1. Not able to finish so had to redo it again

Student2. Submit (ed) before completing calculations because of time; did not understand how to use computer.

Student3. Did activity twice because of …; nervous because first time to use computer.

Activity 2?

Student3. did it once

Student2. not yet used to computer, did once but poor

Student1. not yet used to computer, did 3times but poor

Resources ?

Student1. Understandable

Student2. Understandable and useful

Student3. Problematic at first because no basics of trig . Now I read notes and understand.

Forwarding the video ok

Quiz?

Student2. sometime do not read feedback, just click try again

Student3. quiz in activity 3 was problematic , tried several times but failed

Cos 55 = x/40; x=40cos55 = 22.9

Submission ?

Student3. did not know that submit two times : self-evaluation and test

Session 2: 5 students: one student at a time

How did you do the activities?

Student4. Weak student (did only two activities out of the five); female

How many times did you try activity 1;

Three

Process

How did you go about doing the activity?

I was assisted by the student sitting next to me.

Do roughly, on the side

Then input into computer

(*If answer is wrong?*) that is when I start to ask someone to assist me.

(*so you do not look here (resources*) I Did not think about looking at examples until you (tutor) showed me examples, there was improvement

Challenges

I see you are not moving, what is the problem?

Trig is difficult

(*did you do it high school*) yes did it at high school

(*remember I showed you example (video)?*) I became aware how it is done, things became better.

Student5. Good student (moving faster than other students; good marks in all activities), male

Process

How did you go about doing the activity?

Work out sum, calculate it twice to make sure it is correct

Do not panic when I see that it tough, be patient

If I not understand I ask. (*who*) tutor or peer who explain what it says

(*if you experience problem, do you refer to resources?*) I do look at them, because sometimes you may think that you know, but not

Challenges

(Quiz ?) no

(Videos?) no

(*Test ?*) yes, some questions seem to have something that you missed out.

(What do think I need to make work better?) make sure there is pictures,

Student6. Medium student , male

Process

How did you go about doing the activity?

I start with examples then test

(*you do not do quiz?*) quiz is the one on top ? the small

Activity, I start here (resource), then Quiz, then test

Take exam pad and calculate, then write answer in computer

Challenges

(*Quiz?*) examples are clear, but when you do quiz !!!!

(*Test?*) Tricky some of questions, where there is something which you have to do before
(*you should be getting 100%*) my problem is cross multiplication
Sometimes I do calculations and the answer is right, when I put the steps, it is wrong.
Do not know how to put steps; Steps are different from the way done in high school

Student7. Good student, female (good marks in all activities)
background in trig good, it is the basics, did it grade 10, 11 and 12

Process
How you go about doing the activity?)
Start with quiz, if stuck I go to examples and try to remind myself
(*Test ?*) apply theory

Challenges
Quiz, rounding off answer wrong
(Any problems with examples?) no
(*Test?*) no
(*Success?*) understand instructions/questions, Sometimes I do not read instructions,

Students8. Good student, male
Process ?
How you go about doing the activity?)
Open activity, start with quiz, do calculations
(*you do not look resources?*) did not look at notes, because I think I know
then do test => self-efficacy face challenging tasks head-on

Challenges
Activity five had mistakes (***is that why you got 60%?***)
No challenges
Use of computer /Technology is good, writing is more efficient, give chance to write down if they feel like. Using computer is confusing to some people.

Appendix 5: Know-Want to learn-Learned.

Know	**W**ant to learn	**L**earned

Objective	**K**now **W**ant to learn
1. Identifying sides of a right-angled triangle with respect to a given angle.	
2. Defining trigonometric ratios for angles in right-angled triangles	
3. Using trigonometric notation e.g., sin A	
4. Using a calculator to find approximations of the trigonometric ratios of a given angle measured in degrees	
5. Using a calculator to find an angle correct to the nearest degree, given one of the trigonometric ratios of the angle	
6. Selecting and using appropriate trigonometric ratios in right-angled triangles to find unknown sides	
7. Selecting and using appropriate trigonometric ratios in right-angled triangles to find unknown angles correct to the nearest degree	
8. Solving problems involving the use of right angle trigonometry	

Appendix 6: LMS Data

6.1 Cycle 1

Examples of short answers question

a. LMS short answer question grading instructions

Grade Responses: Trigonometry - Short Answer

Click **Hide User Names** to grade these responses anonymously. Click **Show Usernames** to display user information. Expand the **Question Information** section to display or hide question details,and to edit the question, the entire test or to assign full question credit to the current user. More Help

b. Examples of student short answers

Example 1	Example 2	Example 3
Submitted Date: 19-Aug-2014 12:36 **Given Answer:** $a^2+b^2=c^2$ $b^2=6^2+8^2$ $b^2=100$ $b=10$	**Submitted Date:** 16-May-2014 08:38:44 **Given Answer:** $b^2=a^2+c^2$ -2ac.CosB $b^2=6^2+8^2-2(6)(8)Cos90$ b^2 =100-96.Cos90 b^2 =100 b=$\sqrt{100}$ b=10	**Submitted Date:** 19-Aug-2014 13:19:00 **Given Answer:** $c^2+a^2=b^2$ $8^2+6^2=b^2$ $\sqrt{8^2+6^2}=b$ $b=\sqrt{64+36}$ $b=\sqrt{100}$ $b=\pm 10$

c. Examples of Issues relating to set-system-answers

Activity 1

Issue description	No. of cases (out of 14 attempts)	Examples
Question1: Name sides of a right triangle		
1. Student used the correct format (as indicated in the Toolbox) and got one right answer. The system allocated 0 mark.	7	Working Area AB = HYPOTENUSE AC = OPPOSITE BC = ADJECENT Tool Box opposite adjacent hypotenuse right angle
Observation1: No provision for partial credit was made.		
2. Student used the wrong format, i.e., symbol instead of the full word.	2	Working Area AB = C AC = B BC = A Tool Box opposite adjacent hypotenuse right angle
Observation2: Acceptable format indicated in Toolbox is not clear		

3. No answer given	2	Working Area AB = ✗ [None Given] AC = ✗ [None Given] BC = ✗ [None Given] Tool Box opposite adjacent hypotenuse right angle
Observation3: no attempt		
Question2 Define the trig ratios with-respect-to a given angle		
4. Correct answer marked wrong by LMS due to spelling error.	3	Working Area Sine ϴ = ✓ opposite/hypotenuse Cosine ϴ = ✗ adjacent/hpotenuse Tangent ϴ = ✓ opposite/adjacent Tool Box opposite/adjacent opposite/hypotenuse adjacent/opposite adjacent/hypotenuse
Observation4: No provision for typing errors		

Activity 2

Issue description	No. of cases (out of 6 attempts)	Examples
5. No attempts	0	
Observation5: No student attempted this activity. Why?		

Activity 3

Issue description	No. of cases (out of 6 attempts)	Examples
Question 2: Relationship between corresponding side and angles of similar triangles		
6. Challenge in completing questions.	6	1. Two figures are similar if: The measures of their corresponding ✓ **ANGLES** are equal and the lengths of their corresponding sides are related by the same factor, called the ✗ **RECTANGLE** factor. Similar figures have the same ✗ **SCALE** and are ✓ **PROPOTIONAL** copies of one another. **Tools** scale angles shape proportiona 2 Look at triangles OAQ and OBP in Figure 13 2.1 Which angles are equal? ✗ **OP** 2.2 What are the Corresponding sides? ✗ **OB AND OP** 2.3 Complete: AQ/BP = …✗ **THEY AREPARALLEL**/✗ **AQ=BP** OQ OA OP OB
Observation6: answer format is too constraining		

Activity 4

Issue description	No. of cases (out of 13 attempts)	Examples
Question1: Write a mathematical representation. Pythagoras theorem		

7. Correct answer marked wrong by LMS	7	Student answer In a right triangle, the sum of the squares of the measures of th legs equals the square of the measure of the hypotenuse From Figure 14 write a math expression to represents this statement. **Representation: Write a^2 as a^2 ; b^2 as b^2 etc.** Expression: ✗ **b^2=c^2+a^2** (HINT) System answer **Evaluation Correct Answers for: a** **Method** *Contains* b^2=a^2+c^2
Observation7: No provision for alternative answers		
Question2: Calculate the value of the missing side		
8. Pythagoras theorem correct, but square root not taken	8	Expression: ✗ **a^2 + b^2 =c^2** (HINT) Use your formula to calculate **a** when b = 13 and c =5 => **a =** ✗ **13^2 -5^2**
Observation8: The student's answer is not in a simplified form; the system answer is in simplified form (answer format) This could be a conceptual/mathematical error, or a technical error (not knowing how to indicate the square root)		
Question3:		
9. Challenge to write x^2 in the required format, i.e... x^2	7	a) In Figure 16, AB = c, BC = a and AC = b Write to write an expression for the quickest way of calculatin hypotenuse side **b** using a Scientific calculator. **Representation: Write a^2 as a^2; b^2 as b^2 and** **√(a) as (a)^1/2 etc.** Expression: ✗ **[None Given]** (HINT) b) Use your expression to calculate **b** when a = 6 and c = 8 **=> b=** ✓ **10**
Observation9: Required format is too constraining		

Activity 5

Issue description	No. of cases (out of 8 attempts)	Examples
10. Correct answer marked wrong by LMS.	6	We can use the ✓ **tan** ratio to solve for x Therefore ✗ **tan70 = x/40** ✗ **x = 40*tan 70** ✗ **x = 109.9** ✗ **[None Given]**
Observation10: Steps in student answer do not correspond with set-system-answers		

6.2 Cycle 3

System responses

1) Test-Attempts statistics

Activity	Question	Correct answer (%)	Partially correct (%)	Not answered (%)	a	b	c	d	e	f	g	h	i	j	k
1	1 fmb	70	17.5	5	80	75	80								
		75	20		83	88	83								
	2 fmb	77.5	12.5	7.5	80	80	88								
	3 fmb	57.5	25	7.5	78	70	75	68							
	4 fmb	45	22.5	12.5	53	63	55								
2	1 ma				84	92	89								
	2 ma				81	89	92								
	3 ma				89	92	84								
	4 fmb	0	100	0	97	95	97	81	5	84	0	0	95	0	95
		70	30						89	86	92	95	97	97	97
	5 fmb	38	62	0	97	95	100	100	92	92	97	38			
		68										70			
3	1 fmb	44	50	3	88	66	63	78							
		56	41		91	78	71	84							
	2 fmb	0	100	0	6	93	88	63	0						
		41	59		81				59						
	3 fmb	13	84	0	75	72	44	66	81	88	59	53	59		
		31	69		91	88	81	78							

4	1 fmb	57	39	0	93	71	82								
		75	25			96									
	2 fmb	28	71	0	89	82	85	82	60	68					
									??	??					
	3 fmb	0	100	0	85	82	89	85	57	0					
		29	71		89	89	89		??	71					
5	1 fmb	42	58	0	79	83	83	75	91	58					
	2 fmb	0	100	0	92	0	10 0	67	92	45					
		42	58			83									
	3 fmb		100		96	0	0	62	83	63					
		46	54			96	96	66							
	4 fmb	58	42	0	100	96	92	71	83	67					

Design Error Analysis Key

>80	Acceptable student errors	
60-79	System answer error-tolerance	e.g. spelling, syntax
< 60	System answer contains minor errors	e.g. evaluation method; “exact” Vs “contains”
0	System answer contains major error	e.g. totally wrong
85	Results after system error correction	

2) Example Column statistics

Points Possible	100
Description	

STATISTICS

Count	134
Minimum Value	21.00
Maximum Value	81.00
Range	60.00
Average	65.19
Median	67.50
Standard Deviation	10.76
Variance	115.78

STATUS DISTRIBUTION

Null	62
In Progress	0
Needs Grading	15
Exempt	0

GRADE DISTRIBUTION

Greater than 100	0
90 - 100	0
80 - 89	2
70 - 79	58
60 - 69	50
50 - 59	13
40 - 49	5
30 - 39	3
20 - 29	3
10 - 19	0
0 - 9	0
Less than 0	0

2) System/Student Errors

Activity 2

Q1. 1 of the 3 answers given.

Q4.

Working Area

AB^2 = ✓ **AC^2** ✓ **+** ✓ **BC^2**

✓ **25** ^{2} = AC^2 ✗ **+** ✓ **7** ^{2}

AC^2 = ✗ **25** ^{2} ✗ - ✓ **7** ^{2}

AC^2 = ✗ **576**

∴ AC = ✓ **24**

Calculate the value of AC in Δ ABC (Fig 1), if AB = 25 and BC = 7

Working Area

AB^2 = [a]^2 [b] [c]^2

[d]^2 = AC^2 [e] [f]^2

AC^2 = [g]^2 [h] [i]^2

AC^2 = [j]

∴ AC = [k]

design error;

Q5

Working Area

Calculate the value of KL in Δ KLM (Fig
nd KM = 24

KL^2 = ✓ **KM^2** + ✓ **LM^2**

KL^2 = ✓ **24** ^{2} + ✓ **8** ^{2}

KL^2 = ✗ **24** + ✗ **8**

KL^2 = ✓ **640**

∴ KL = ✗ **25.2**

Working Area

Calculate the value of KL in Δ KLM (Fig 22), if LM = 8 a
nd KM = 24

KL^2 = ✓ **LM^2** + ✓ **KM^2**

KL^2 = ✓ **8** ^{2} + ✓ **24** ^{2}

KL^2 = ✗ **[None Given]** + ✗ **[None Given]**

KL^2 = ✓ **640**

∴ KL = ✗ **25.30**

Fig 22

student error; 24 and 8 not squared, rounding in answer

design error: steps 2 an 3 can be done once/combined using a calculator

=> remove step 3

Activity 3

Q1. Instructions not clear ???

sinC= AB/✓ **AC**
sin70 = x/117
x = ✗ **117sin70**✗ **109.9440366**
x = ✓ **109.9** to 1 decimal place

sinC= AB/**[a]**
sin70 = x/117
x = **[b][c]**
x = **[d]** to 1 decimal place

student error; use of calculator.

design error two spaces [b][c] for one answer 117sin70

Q2

Given: BC is **opposite** side and x is the **adjacent** side W
e can use the tangent ratio to solve for x.

Therefore
tanA = ✗ **OPPOSIT/ADJACENT**
tan62 = ✓ **3/X**
x = ✗ **TAN62/**✗ **3**
x = ✗ **5.6** to 1 decimal place

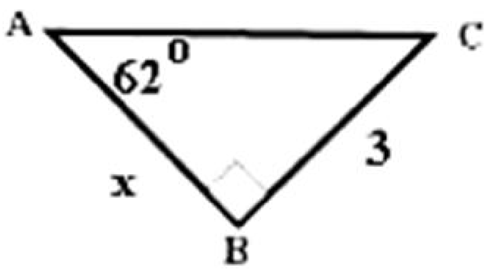


Fig15

student error; solving simple equation

Q3

#design error; multiplication is commutative => 40cos55 or cos55*40 both correct

Activity 1

Q1. Spelling, e.g. ✗ **hypotenus,** ✗ **opposite side**

 # design error: error intolerance low,

=>include hint on spelling, give example of format

Q2. Naming **5cm,** hypotenuse = ✗ **HF (cf FH)**

Student error: including units

=> instructions not clear?, give example of format

Q3. Not catered for AC/BC = ✗ **cota,** BC/AC = ✗ **COTB**

design error: format not specified

=> instructions not clear?, give example of format

Q4. Instructions missed/not clear SinΘ = ✗ **opposite/hypotenuse**

=> instructions not clear?, give example of format

Q5. Not submited only one of two submissions

Activity 5

Q1

Find the length of **a** in this triangle

a	=	✗ **10m**
✓ **Sin41**		✓ **Sin34**
a	=	✗ **10msin41**
		✓ **sin34**
a	=	✓ **11.7**

Student error: syntax (remove units)

System error: required/acceptable format not clarified

Q2

Working area

Find the length of **x** in this triangle.

x	=	✓ **5.2**
✗ **sin61**		✓ **sin62**
x	=	✗ **5.2xsin61**
		✓ **sin62**
x	=	✓ **5.2**

.

Student error: syntax (remove x)

design error: give example of format

Q3. # student error: incorrect information

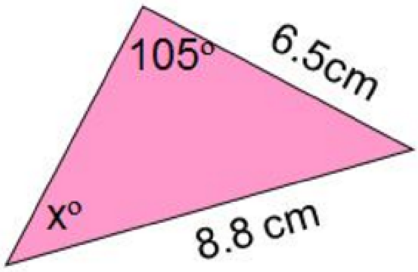
Working area

Find the value of **x** in this triangle.

Sinx = sin1
6.5 08
8.8

Sinx = 6.5sin108
8.8

x = 45



LMS: Change Logs

Activity 1

Q1. a, b, c, d changed evaluation method from “*exact*” to “*contains*” hyp, adj, cos

Q3. answer format not well-defined; give example of format

Q4. answer format not well-defined; give example of format

Activity 2

Q1-3 No change

Q4. System answers for parts e, g, h, j, captured in wrong order, were rectified.

Q5. Answer 25.3 changed to include 25,3 ; 25.30 ; 25,30

Activity 3

Q1. a, b, c, d added alternative answers observed from students responses

a = AC & x, b = 117& sin70, sin70 & 117, c = 109.9 & 109,9

Q2. System answers for parts a, changed BC/AC to BC/AB; e, changed 2 to 1.6 /1,6

Q3. a, b, c, d changed evaluation method from “*exact*” to “*contains*” hyp, adj, cos to accommodate typos.

Activity 4

Q1. answer for part b; 3 or 24/8

Q2. d and e changed evaluation method from “*exact*” to “*contains*” hyp, adj, cos to accommodate typos.

Q3. d and e changed evaluation method from “*exact*” to “*contains*” hyp, opp, cos to accommodate typos.

Activity 5

Q1. No change

Q2. No change

Q3. No change

Q4. No change

Activity 4

Q1.

tan Θ = ✓ **24/8** (ratio = fraction)

Θ = $\tan^{-1}$ ✗ **24/8**

Θ = ✓ **71.6** to 1 decimal place

design error answer 3 or 24/8

Q2.

In Fig 24, determine the value angle X?

Working area

Given: the lengths of the sides ✗ **adjacemt** to t he angle, and the ✗ **hypotenus** side.

Therefore

✓ **cosx** = ✗ **[None Given]** (define trig rat io)

X = $\cos^{-1}$ ✓ **5/13**

X = ✓ **67.4** to 1 decimal place

Resources

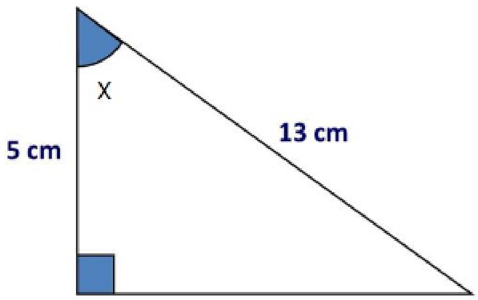


Fig 24

Student error: spelling (minor)

system error: spelling error tolerance low

Q3 . Question design error => check answer

Given: the lengths of the side ✗ **15** and the side ✗ **17** to the angle,

✓ **SINX** = ✓ **15/17**

X = $\sin^{-1}$ ✓ **15/17**

X = ✗ **61.9** to 1 decimal place

Question design error => check answer

6.3 Cycle 4

1) . Examples of Access Logs

Cycle 4

Student 1 (Attempt 1 of 1) 54 minutes, Good performer, 100%

Access Log

There is no start time recorded for this attempt as it was taken prior to the Learn version when start times were included in archives.

Date and Time	Access Type	Test Time	Time Spent*
23/02/17 11:14:36	Test submitted	00:00	00:00
23/02/17 11:53:05	Saved question 1 multiple times over a period of: 17:26	38:29	38:29
23/02/17 11:54:34	Saved question 2 multiple times over a period of: 00:17	39:58	01:28
23/02/17 11:57:10	Saved question 3 multiple times over a period of: 01:22	42:34	02:36
23/02/17 11:59:08	Saved question 4 multiple times over a period of: 01:06	44:32	01:57
23/02/17 12:08:37	Saved question 5	54:01	09:29

*The times appearing under the Time Spent column may not accurately represent the time the student spent on each question. The student may have looked at other questions before answering and saving individual questions.

Student 2 (Attempt 1 of 2) 1 hour, 9 minutes; Good performer 87%

Access Log

There is no start time recorded for this attempt as it was taken prior to the Learn version when start times were included in archives.

Date and Time	Access Type	Test Time	Time Spent*
23/02/17 11:13:36	Test submitted	00:00	00:00
23/02/17 12:04:31	Saved question 1 multiple times over a period of: 00:41	50:55	50:55
23/02/17 12:07:57	Saved question 2 multiple times over a period of: 00:44	54:21	03:25
23/02/17 12:16:34	Saved question 3 multiple times over a period of: 06:55	02:58	08:36
23/02/17 12:19:30	Saved question 4 multiple times over a period of: 01:34	05:54	02:56
23/02/17 12:20:04	Saved question 5	06:28	00:33
23/02/17 12:22:32	Saved question 4	08:56	02:28

*The times appearing under the Time Spent column may not accurately represent the time the student spent on each question. The student may have looked at other questions before answering and saving individual questions.

1) Test-Attempts statistics

Activity	Question	Correct answer (%)	Partially correct (%)	Not answered (%)	a	b	c	d	e	F	g	h	i	j	k
1	1 fmb	92	5	0	95	97	92								
	2 fmb	90	11	0	95	95	95								
	3 fmb	37	61	0	74	63	84	82							
	4 fmb	61	26	0	79	68	76								
2	1 ma														
	2 ma														
	3 ma														
	4 fmb	55	40	5	87	95	87	87	90	90	82	80	82	92	90
	5 fmb	53	42	5	90	84	95	95	95	95	95	61			
3	1 fmb	56	44	0	94	78	67	86							
	2 fmb	58	42	0	97	86	83	78	86						
	3 fmb	42	58	0	75	64	78								
4	1 fmb	63	31	3	80	83	83								
	2 fmb	40	60	0	80	66	74	94	91	100					

	3 fmb	46	54	0	83	71	86	94	89	94					
5	1 fmb	42	58	0	83	78	81	67	92	72					
	2 fmb	31	69	0	86	94	94	53	92	58					
	3 fmb	100	100	0	58	79	75								
	4 fmb	50	50	0	10 0	97	10 0	64	94	83					
6	1 fmb	22	72	3	84	84	59	78	78	50	72				
	2 fmb	16	81	3	97	63	72	69	72	53	72	72	72	41	66
	3 fmb	25		3	63	75	69	66	50	94	69	66	44	63	
	4 fmb	0	97	3	69	84	84	84	41	91	81	81	53	6	

System Error Indicator Key

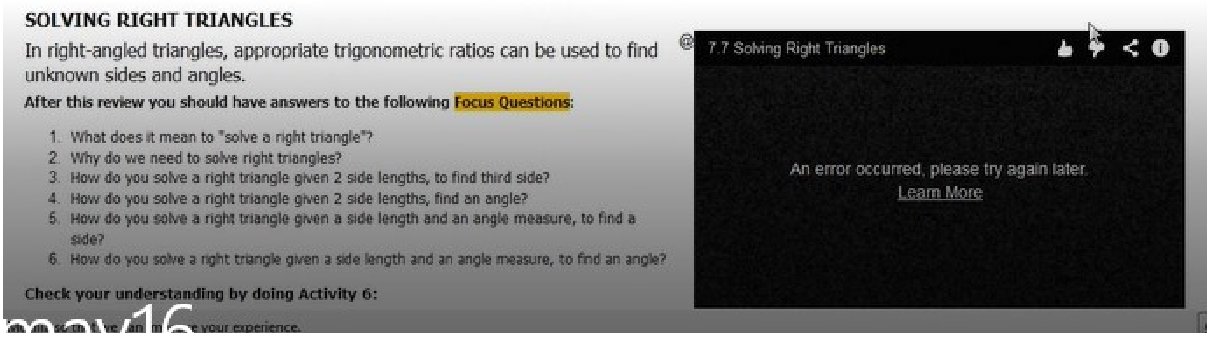
>80	Acceptable student errors	
60-79	System answer error-tolerance	e.g., spelling, syntax
< 60	System answer contains minor errors	e.g., evaluation method; “exact” Vs “contains”
0	System answer contains major errors	e.g., totally wrong
85	Results after system error correction	

Appendix 7: Screen capture-video transcript

7.1 Cycle 1

Example of Screen capture-video

Time lapse	Student action
1.41	Login
4.19	Chose module
6.29	Open tutorial
10.14	Scan objectives page
12.51	Do KWL questionnaire
16.20	KWL complete
16.46	Re do KWL questionnaire
19.33	Objectives page
19.38	Open activities page
19.44	Open Activity1
20.35	Scroll down to tutorial questions
37.31	Submit Activity1
38.25	Back to activities page; chose Activity4
38.32	Open Activity4
38.41	Scroll down to tutorial questions
44.54	Start working, open calculator
45.10	Change calculator to scientific mode
48.05	Submit Activity4
49.18	Open evaluation page (learning journal)
52.48	Complete learning journal
61.07	Submit learning journal
	(did not logout)



SOLVING RIGHT TRIANGLES

In right-angled triangles, appropriate trigonometric ratios can be used to find unknown sides and angles.

After this review you should have answers to the following Focus Questions:

1. What does it mean to "solve a right triangle"?
2. Why do we need to solve right triangles?
3. How do you solve a right triangle given 2 side lengths, to find third side?
4. How do you solve a right triangle given 2 side lengths, find an angle?
5. How do you solve a right triangle given a side length and an angle measure, to find a side?
6. How do you solve a right triangle given a side length and an angle measure, to find an angle?

Check your understanding by doing Activity 6:

Appendix 8: Journal Responses

8.1 Cycle 1

Learning Journal, Total of 10 attempts

1	The task was informative	sa	a	nand	d	sd	u
		28.571%	50%	7.143%	14.286%	0%	0%
2	The task was exciting.	sa	a	nand	d	sd	u
		50%	35.714%	7.143%	0%	0%	7.143%
3	The task was interesting.	sa	a	nand	d	sd	u
		50%	35.714%	14.286%	0%	0%	0%
4	Using e-tools made the task easy	sa	a	nand	d	sd	u
		35.714%	35.714%	14.286%	7.143%	0%	7.143%
5	Using e-tools made the task quick	sa	a	nand	d	sd	u
		35.714%	35.714%	7.143%	14.286%	0%	7.143%
6	When doing the task I felt confident.	sa	a	nand	d	sd	u
		35.714%	35.714%	14.286%	0%	0%	14.286%
7	Using e-tools made the task easy	sa	a	nand	d	sd	u
		35.714%	35.714%	14.286%	7.143%	0%	7.143%
8	Using e-tools made the task easy	sa	a	nand	d	sd	u
		14.286%	50%	14.286%	7.143%	0%	14.286%
9	I am satisfied with the way did the task.	sa	a	nand	d	sd	u
		14.286%	50%	14.286%	21.429%	0%	0%
10	Using the e-tools to do this task was challenging.	sa	a	nand	d	sd	u
		0%	28.571%	42.857%	7.143%	0%	0%
11	Using e-tools made the task easy	sa	a	nand	d	sd	u
		14.286%	35.714%	28.571%	21.429%	0%	0%
12	"I think the content is appropriate for the topic, "	sa	a	nand	d	sd	u
		7.143%	42.857%	14.286%	21.429%	0%	14.286%
13	Using e-tools made the task easy	sa	a	nand	d	sd	u
		35.714%	35.714%	14.286%	7.143%	0%	7.143%
14	I was able to find the information I needed	sa	a	nand	d	sd	u
		35.714%	35.714%	14.286%	7.143%	0%	7.143%
15	I was able to find the information I needed	sa	a	nand	d	sd	u
		14.286%	57.143%	21.429%	7.143%	0%	0%
16	I was able to do the task correctly	sa	a	nand	d	sd	u
		14.286%	50%	28.571%	7.143%	0%	0%
17	I was able to use the e-tools with tutors help.	sa	a	nand	d	sd	u
		50%	28.571%	7.143%	14.286%	0%	0%

18	I was able to use the e-tools with help from a friend.	sa	a	nand	d	sd	u
		21.429%	50%	14.286%	14.286%	0%	0%
19	I was able to use the e-tools by myself.	sa	a	nand	d	sd	u
		35.714%	42.857%	14.286%	0%	7.143%	0%
20	"This task was interesting, "	sa	a	nand	d	sd	u
		42.857%	50%	7.143%	0%	0%	0%
21	I enjoyed doing this task.	sa	a	nand	d	sd	u
		42.857%	28.571%	21.429%	0%	7.143%	0%
22	I was able to seek assistance when needed.	sa	a	nand	d	sd	u
		42.857%	28.571%	14.286%	7.143%	7.143%	0%
23	Use of e-tools makes me to get involved in doing the task.	sa	a	nand	d	sd	u
		28.571%	50%	14.286%	7.143%	0%	0%
24	Use of e-tools helped me to work out the answers.	sa	a	nand	d	sd	u
		35.714%	57.143%	7.143%	0%	0%	0%
25	Using e-tools made the task easy	sa	a	nand	d	sd	u
		35.714%	50%	14.286%	0%	0%	0%

Question 26: Short Answer

What do you need to know more about?

Unanswered Responses 4

Given Answers

HOW TO USE A CALCULATOR

defferentiation and intergration

SOLVING TRIGONOMETRY IDENTIES

CALCULATOR its hard to do tasks without calculator

Whatever is relevant for my growth and developnment.

differentian and intergration

i need to know more about using trigonometric ratios and usimg a calculator to get correct answers.

DEFFERENTIATION

Just to get farmiliar with the programme

Question 27: Short Answer

What did you find puzzling or challenging?

Unanswered Responses 4

Given Answers

finding the missing angle

NONE

Lauch maths editor launch maths

Nothing so far.

I couldnt get all equesions example sine rule

right angle triangfle

challenimg

The was easy but need an attention

i found that using e-tools is not easy as i thought.

8.2 Cycle 2

Learning Journal, Total of 14 attempts

1	The task was informative	sa	a	nand	d	sd	u
		28.571%	50%	7.143%	14.286%	0%	0%
2	The task was exciting.	sa	a	nand	d	sd	u
		50%	35.714%	7.143%	0%	0%	7.143%
3	The task was interesting.	sa	a	nand	d	sd	u
		50%	35.714%	14.286%	0%	0%	0%
4	Using e-tools made the task easy	sa	a	nand	d	sd	u
		35.714%	35.714%	14.286%	7.143%	0%	7.143%
5	Using e-tools made the task quick	sa	a	nand	d	sd	u
		35.714%	35.714%	7.143%	14.286%	0%	7.143%
6	When doing the task, I felt confident.	sa	a	nand	d	sd	u
		35.714%	35.714%	14.286%	0%	0%	14.286%

7	Using e-tools made the task easy	sa	a	nand	d	sd	u
		35.714%	35.714%	14.286%	7.143%	0%	7.143%
8	Using e-tools made the task easy	sa	a	nand	d	sd	u
		14.286%	50%	14.286%	7.143%	0%	14.286%
9	I am satisfied with the way did the task.	sa	a	nand	d	sd	u
		14.286%	50%	14.286%	21.429%	0%	0%
10	Using the e-tools to do this task was challenging.	sa	a	nand	d	sd	u
		0%	28.571%	42.857%	7.143%	0%	0%
11	Using e-tools made the task easy	sa	a	nand	d	sd	u
		14.286%	35.714%	28.571%	21.429%	0%	0%
12	"I think the content is appropriate for the topic, "	sa	a	nand	d	sd	u
		7.143%	42.857%	14.286%	21.429%	0%	14.286%
13	Using e-tools made the task easy	sa	a	nand	d	sd	u
		35.714%	35.714%	14.286%	7.143%	0%	7.143%
14	I was able to find the information I needed	sa	a	nand	d	sd	u
		35.714%	35.714%	14.286%	7.143%	0%	7.143%
15	I was able to find the information I needed	sa	a	nand	d	sd	u
		14.286%	57.143%	21.429%	7.143%	0%	0%
16	I was able to do the task correctly	sa	a	nand	d	sd	u
		14.286%	50%	28.571%	7.143%	0%	0%
17	I was able to use the e-tools with tutors help.	sa	a	nand	d	sd	u
		50%	28.571%	7.143%	14.286%	0%	0%
18	I was able to use the e-tools with help from a friend.	sa	a	nand	d	sd	u
		21.429%	50%	14.286%	14.286%	0%	0%
19	I was able to use the e-tools by myself.	sa	a	nand	d	sd	u
		35.714%	42.857%	14.286%	0%	7.143%	0%
20	"This task was interesting, "	sa	a	nand	d	sd	u
		42.857%	50%	7.143%	0%	0%	0%
21	I enjoyed doing this task.	sa	a	nand	d	sd	u
		42.857%	28.571%	21.429%	0%	7.143%	0%
22	I was able to seeks assistance when needed.	sa	a	nand	d	sd	u
		42.857%	28.571%	14.286%	7.143%	7.143%	0%
23	Use of e-tools makes me to get involved in doing the task.	sa	a	nand	d	sd	u
		28.571%	50%	14.286%	7.143%	0%	0%
24	Use of e-tools helped me to work out the answers.	sa	a	nand	d	sd	u
		35.714%	57.143%	7.143%	0%	0%	0%
25	Using e-tools made the task easy	sa	a	nand	d	sd	u
		35.714%	50%	14.286%	0%	0%	0%

Question 26: Short Answer

What did you find puzzling or challenging when you were doing the task?

Unanswered Responses 5

Given Answers

NONE

naming sides of right angle triangle

Lack of understanding some few things

launch maths aditor

usibg the computer to slovethe promble (using the computer to solve the problem)

i coundn't understand the question more clearly

finding misssing angle

nothing yet.

I find a bit of sophistication

Question 27: Short Answer

What do you need to know more about?

Unanswered Responses 5

Given Answers

finding the missing angle

In order for me to succed in life i would like to came across with some more interesting question

want know to use a computer

How to use it properly

launch maths aditor

i need to know more about using e-tools stuff natural logarithimic trigonometry

HOW DO I GET MY RESULTS

Anything relevant to my studies.

8.3 Cycle 3

1) Summary of Journal responses

Activity	Count	Journal responses	%
1	40	32	80
2	37	34	92
3	32	17	53
4	28	16	61
5	24	10	42

2) Journal results

a) Exciting

	Introduction	Quiz	Notes pdf	Presentation video	Test	None	Other
Activity 1 Responses =32							
Interesting	3.1% (1)	37.5% (12)	15.6% (5)	9.4% (3)	50% (16)	12.5% 6	6.3% (2)
Challenging	0% (0)	28.1% (9)	3.1% (1)	9.4% (3)	21.9% (7)	50% (16)	0% (0)
Frustrating	3.1% 1	9.4% 3	0% 0	6.3% 2	3.1% 1	78.1% 25	0% 1
Activity 2 Responses =34							
Interesting	11.8% 4	47.1% 16	8.8% 3	17.6% 6	55.9% 19	8.8% 3	5.9% 2
Challenging	5,9% 2	20,6% 7	0% 0	2,9% 1	29,4% 10	52,9% 18	5,9% 2
Frustrating	2,9% 1	17,6% 6	0% 0	0% 0	26,5% 0	55,9% 19	0% 0
Activity 3 Responses = 17							
Interesting	11.8% 2	58.8% 10	17.6% 3	5.9% 1	58.8% 10	5.9% 1	0% 0
Challenging	5,9% 1	23,5% 4	0% 0	0% 0	23,5% 4	52,9% 9	0% 0
Frustrating	0% 0	23,5% 4	0% 0	0% 0	29,4% 5	47,1% 8	5,9% 1
Activity 4							

Responses = 20							
Interesting	0% 2	56.3% 9	12.5% 2	12.5% 2	37.5% 6	6.3% 1	0% 0
Challenging	6,3% 1	31,3% 5	0% 0	0% 0	31,3% 5	43,8% 7	0% 0
Frustrating	6,3% 1	37,5% 6	0% 0	0% 0	25% 4	43,8% 7	0% 0
Activity 5 Responses = 17							
Interesting	0%1	40% 4	10% 1	10% 1	50% 5	10% 4	0% 1
Challenging	0% 4	40% 4	0% 0	60% 6	20% 2	40% 4	0% 0
Frustrating	0% 0	30% 3	0% 0	0% 0	60% 6	30% 3	0% 0

Students Comments

Introduction

Introduction and notes were interesting because they helped me understand the quetions i had to answer through

Quiz

Because it reminded me the previous grades work

I find that the quiz qestion test your knowledge and playing with figueres. But in question7 in quiz i found a little confusion at the start. I enjoy this question because it makes me to recall the trigonometric ratios from grade 10.

Notes

No comments

Video

No comments

Test

It tested my knowledge, and also tested my comprehension skills, meaning it was testing if i can read and follow

It was easy to follow it because it remembering me the previous learn from the lower classis

Test it was interesting because it was more challenging it was also need concentration and focus.

None

It was all normal, nothing particularly interesting.

b) Confidence

Activity 1	Q1	Q2	Q3	Q4	None
Do easly	78.1% 25	53.1% 17	50% 16	37.5% 12	9.4% 3
Do by self	81.3% 26	71.9% 23	68.8% 22	65.6% 21	0% 0
Do with tutors help	3.1% 1	6.3% 2	3.1% 1	9.4% 3	84.4% 27
Do with peers help	3.1% 1	12.5% 4	12.5% 4	9.4% 3	75% 24
Activity 2					
Do easly	85,3% 29	79,4% 27	61,8% 21	61,8% 21	2,9% 1
Do by self	94,1% 32	88,2% 30	88,2% 30	73,5% 25	2,9% 1
Do with tutors help	2,9% 1	5,9% 2	11,8% 4	29,4% 10	64,7% 22
Do with peers help	2,9% 1	5,9% 2	5,9% 2	20,6% 7	76,5% 26
Activity 3					
Do easly	70,6% 12	52,9% 9	58,8% 10	35,3% 6	17,6% 3
Do by self	70,6% 12	58,8% 10	52,9% 9	41,2% 7	29,4% 5
Do with tutors help	5,9% 1	5,9% 1	11.8% 2	17,6% 6	82,4% 14
Do with peers help	0% 0	0% 0	0% 0	5,9% 1	94,1% 16
Activity 4					
Do easly	87,5% 14	68,8% 11	62,5% 10	62,5% 10	12,5% 2
Do by self	87,5% 14	68,8% 11	75% 12	75% 12	0% 9
Do with tutors help	0% 0	0% 0	6,3% 1	6,3% 1	87,5% 14
Do with peers help	0% 0	0% 0	6,3% 1	0% 0	93,8% 15
Activity 5					
Do easly	80% 8	60% 6	50% 5	60% 6	20% 2
Do by self	90% 9	80% 8	80% 8	90% 9	10% 1
Do with tutors help	0% 0	0% 0	10% 1	0% 0	90% 9
Do with peers help	0% 0	0% 0	0% 0	0% 0	100% 10

Students Comments

Do easly

i think they were not challenging

all of the questions were easy

because i understand the topic

all of them were clearly to me but again in pre test 2 there were some question which were difficult that is why i got that marks

Do by self
because i understand the topic
all of them
didn't get any help from anyone.
everything was understandable
because i wanted to check wheather i can manage to answer
They were easy to workout.

Do with tutors help
i found it challenging
because there was an error
it was challenging to me
there was an error
i had difficulties in spotting the x, y, and x
it was complicated
complecated question for me when it comes on filling spaces

Do with peers help
Question 4
no help from no one
i wasn't sure what was being asked of me
it was a tricky for me
question 4 had a mistake with the allocation of signs so i was able to assist my peers with that

None
because i wanted to test myself
because i was confident and positive about my calculations.
i wanted to do it all by myself
it because the tutor already helped me with the question that i found difficult.
i want see that i can do the activity by myself

i believe in answering everything by myself

i did them by myself

Question 2, Question 3

it was too hard for me

c) Satisfaction

Activity 1	Very well 100%	About 75%	About 50%	About 30%	not well, < 30%	
understand the work	29% (9)	54.8% (17)	12.9% (4)	3.2% (1)	0% (3)	

Students Comments

I DID NOT GET FULL MARK

IT IS EASY TO UNDERSTAND

id say 100 however the final three of the quiz got the better of me!

I GOT MORE THAN 75 PERCENT

ITS THE PERSENT THAT I MANAGED.

I asked everything i needed to know so i think up to so far im covered

IT WAS GRADE STUFF SO I WAS REVISING

IT WAS RATHER DEFICULT TO ME TO UNDERSTAND IT 100%

the test wasnt challenging

as I have said it wasn't challenging

I WAS NOT TOO SURE ABOUT ALL MY ANSWERS

I KNOW EVERYTHING HERE ESPECIAL IT TALKS ABOUT TRIGONOMETRY

ITS not much difficult but it needs you to focus and analise the questions

because i still have small mistakes om this topic

At about 75 percent and above

about 75 percent and above

it was clear

d) Quiz feedback

QUIZ feedback	was informative	was easy to follow	was not clear	directed me where	was useless	

				to study in resources		
	30% 9	63.3% 19	6.7% 2	10% 3	3.3% 1	

3) Summary of Journal responses

Focus area	Observation
1. Response rates	Activity1: 80%, Activity2: 92%, Activity3: 53%, Activity1: 61% and Activity 5: 42% (Average: 65%)
2. Student engagement (average)	Attitude What part(s) of the Activity did you find interesting?) 2.1 Test: (average response was 50%) because: "the questions was straight forward" "it demanded thinking" "it was clear and easy to follow it" "..test to see how far we understand this topic" "Test it was interesting because it was more challenging it was also need concentration and focus" 2.2 Quizlets: (average response was 48%) because: "it had simple questions and was understandable" "it prepared me for what was to come in the test" "quick feedback" "we learnt how to approach different questions" "I find that the quiz qestion test your knowledge and playing with figueres. But in question7 in quiz I found a little confusion at the start." 2.3 Notes:(average response was 11%) because: ".. notes were interesting because they helped me understand the questions I had to answer through" 2.4 Video: (average response was 9%) (No comments) (What part(s) of the Activity did you find challenging?) 2.5 None (average response was 48%),

	because: “they were clear” “they were all easy” “there were no challenges because it was too basic” 2.6 Quizlets (average response was 33%), (No comments) 2.7 Test: (average response was 24%) because: “there are questions that were so tricky in the test but i do answer it “I took lot of time to answer it” “I wasn't sure of all my answers” 2.8 Notes: (average response was 1%); (No comments) 2.9 Video:(average response was 2%) (No comments) 2.10 (What part(s) of the Activity did you find frustrating?): None 51%, (No comments) Quizlets 33%, (No comments) Test 24%; (No comments) Video1%; (No comments) Notes0%; (no comments) (How did you feel when you were doing the Activity?) 2.11*Calm, relaxed*: (average response 60%) because: “there was no strictly period to finalise the test” “because I understand the topic” “the task was so clear and understandable” 2.12 *Nervous, tense*:(average response 20%) because: “i was afraid it might be difficult” “it is my first time i use a computer” “i was not certain about all the questions” “some of the questions were more tricky”
3. Sample Comments	Confidence

	3.1 I did activities by myself: (average response 70%) "because i understand the topic" "because i wanted to check whether i can manage to answer" "because i wanted to test myself" "it is not much difficult but it needs you to focus and analise the questions" 3.2 I received assistance from the tutor: (average response 7%) "because there was an error" "complicated question for me when it comes on filling spaces" "i had difficulties in spotting the x, y," 3.3 I received assistance from peers: (average response 4%) "i wasn't sure what was being asked of me" "question 4 had a mistake with the allocation of signs so i was able to assist my peers"
	Satisfaction (How well did you understand the work covered in this activity?) 3.4 well (got 75-100%) average response 84% "it was rather difficult to me to understand it 100%" "not much difficult but it needs you to focus and analyse the questions" "I asked everything i needed to know so i think up to so far im covered" 3.5 not well (got 30% or below) average response 3% (*two students*) (No comments)
	Quizlets feedback Quizlets feedback 3.6 was easy to follow 63% (No comments) 3.7 was informative 30% (No comments) 3.8 directed me where to study in resources 10% (No comments) 3.9 not clear 7%, (No comments) 3.10 was useless 3% (No comments)

8.4 Cycle 4

1) Summary of Journal responses

Activity	Count	Journal responses	%
1	49	34	88
2	45	29	64
3	45	32	71
4	40	29	73
5	46	13	28
6	45	34	76

2) Journal results

a) Exciting

Activity	Introduction: Big idea/concept	Quiz	Notes pdf	Video	Test	None
1 (Responses = 34)						
Interesting	16 (47.1%)	28 (82.4%)	15 (44.1%)	11 (32.4%)	23 (67.6%)	0 (0%)
Challenging	0 (0%)	12 (35.3%)	2 (5.9%)	3 (8.8%)	14 (41.2%)	12 (35.3%)
Frustrating	3 (8.8%)	6 (17.6%)	4 (11.8%)	4 (11.8%)	9 (26.5%)	13 (38.2%)
2 (Responses = 29)						
Interesting	9 (31%)	19 (65.5%)	10 (34.5%)	9 (31%)	24 (82.8%)	3 (10.3%)
Challenging	0 (0%)	4 (13.8%)	1 (3.4%)	2 (6.9%)	8 (27.6%)	18 (62.1%)
Frustrating	0 (0%)	1 (3.4%)	1 (3.4%)	2 (6.9%)	6 (20.7%)	22 (75.9%)

3 (Responses = 32)						
Interesting	12 (37.5%)	18 (56.3%)	9 (28.1%)	9 (28.1%)	27 (84.4%)	
Challenging	0 (0%)	6 (18.8%)	1 (3.1%)	1 (3.1%)	3 (9.4%)	21 (65.6%)
Frustrating	0 (0%)	3 (9.4%)	2 (6.3%)	0 (0%)	2 (6.3%)	25 (78.1%)
4 (Responses = 29)						
Interesting	6 (20.7%)	7 (24.1%)	5 (17.2%)	7 (24.1%)	26 (89.7%)	1 (3.4%)
Challenging	0 (0%)	11 (37.9%)	1 (3.4%)	0 (0%)	4 (13.8%)	15 (51.7%)
Frustrating	0 (0%)	15 (51.7%)	1 (3.4%)	0 (0%)	1 (3.4%)	13 (44.8%)
5 (Responses = 13)						
Interesting	5 (38.5%)	7 (53.8%)	6 (46.2%)	7 (53.8%)	12 (92.3%)	0 (0%)
Challenging	1 (7.7%)	1 (7.7%)	2 (15.4%)	1 (7.7%)	2 (15.4%)	8 (61.5%)
Frustrating	0 (0%)	0 (0%)	0 (0%)	3 (23.1%)	0 (0%)	10 (76.9%)
6 (Responses = 34)						
Interesting	8 (23.5%)	12 (35.3%)	10 (29.4%)	8 (23.5%)	23 (67.6%)	2 (5.9%)
Exciting	3 (8.8%)	11 (32.4%)	6 (17.6%)	7 (20.6%)	27 (79.4%)	2 (5.9%)
Difficult	1 (2.9%)	11 (32.4%)	2 (5.9%)	0 (0%)	7 (20.6%)	14 (41.2%)
Frustrating	0 (0%)	8 (23.5%)	0 (0%)	2 (5.9%)	6 (17.6%)	20 (58.8%)

Observations

In Activity 1 ALL part(s) of this Activity found interesting

Interest in Quiz dropped from 28 (82.4%) in Activity 1 to 7 (24.1%) in Activity 4

Interest in Test remained high between 23 (67.6%) and 12 (92.3%)

Students Comments

Introduction: Big idea/concept, Quiz, Notes pdf, Presentation, Test => ALL
I found it interesting and it help me to remember me the things that I have done in high school
Because they opened mind, they also made me aware of what to expect in math and they were interesting.
I found it interesting because it helped me remember some things I did in high school.
It was enjoyable as it is not something new to me.
They remind me of some basics I almost forgot
they were all clear to me
They were easy to understand

Quiz and Test found to be the most interesting throughout the activities

Comments from Activty1

Quiz
It is because like writing test based on quiz because I will see my mistake
it is interesting because I like learning about angle
The quiz gives you feedback right after you are done answering

Test
Because it has taught me where I need to revise and where I don't understand
I found the test interesting because it showed me how much I really know and what I need to work.

Comments from Activty3

Quiz, Test
I found them challenging and I love a challenge.
it was a great way to exercise my brain
it’s easy
it’s very and very interesting
the quiz was very easy didn't even break a sweat
They were challenging for me but excitting
they were easier than I thought
They were much easire

Observations

b) Confidence

Activity 1	Q1	Q2	Q3	Q4	None
Do easly	25 (73.5%)	26 (76.5%)	21 (61.8%)	15 (44.1%)	0 (0%)
Do by self	26 (76.5%)	30 (88.2%)	26 (76.5%)	23 (67.6%)	0 (0%)
Do with tutors help	5 (14.7%)	5 (14.7%)	4 (11.8%)	7 (20.6%)	21 (61.8%)
Do with peers help	6 (17.6%)	4 (11.8%)	6 (17.6%)	5 (14.7%)	22 (64.7%)
Activity 2					
Do easly	23 (79.3%)	21 (72.4%)	23 (79.3%)	19 (65.5%)	1 (3.4%)
Do by self	28 (96.6%)	26 (89.7%)	24 (82.8%)	25 (86.2%)	1 (3.4%)
Do with tutors help	2 (6.9%)	3 (10.3%)	5 (17.2%)	6 (20.7%)	19 (65.5%)
Do with peers help	2 (6.9%)	3 (10.3%)	5 (17.2%)	7 (24.1%)	20 (69%)
Activity 3					
Do easly	28 (87.5%)	30 (93.8%)	29 (90.6%)	19 (59.4%)	0 (0%)
Do by self					
Do with tutors help	4 (12.5%)	5 (15.6%)	4 (12.5%)	5 (15.6%)	23 (71.9%)
Do with peers help	3 (9.4%)	4 (12.5%)	6 (18.8%)	5 (15.6%)	21 (65.6%)
Activity 4					
Do easly	25 (86.2%)	27 (93.1%)	22 (75.9%)	13 (44.8%)	1 (3.4%)
Do by self					
Do with tutors help	0 (0%)	1 (3.4%)	3 (10.3%)	3 (10.3%)	23 (79.3%)
Do with peers help	1 (3.4%)	1 (3.4%)	6 (20.7%)	4 (13.8%)	23 (79.3%)
Activity 5					
Do easly	13 (100%)	13 (100%)	11 (84.6%)	8 (61.5%)	0 (0%)
Do by self					
Do with tutors help	0 (0%)	0 (0%)	2 (15.4%)	2 (15.4%)	10 (76.9%)
Do with peers help	4 (30.8%)	4 (30.8%)	2 (15.4%)	2 (15.4%)	9 (69.2%)
Activity 6					
Do easly	33 (97.1%)	30 (88.2%)	23 (67.6%)	22 (64.7%)	0 (0%)
Do by self					

Do with tutors help	1(2.9%)	2 (5.9%)	4 (11.8%)	2 (5.9%)	28 (82.4%)
Do with peers help	2 (5.9%)	2 (5.9%)	2 (5.9%)	3 (8.8%)	29 (85%)

Observations

c) Satisfaction

Understand the work	Very well 100%		About 75%		About 50%		About 30%		not well, < 30%	
		%		%		%		%		%
Activity 1 (n=34)	8	23.5	17	50.0	8	23.5	1	2.9	0	0
Activity 2 (n=42)	17	40.5	16	38.1	8	19.0	1	2.4	0	0
Activity 3 (n=35)	18	51.4	9	25.7	6	17.1	2	5.7	0	0
Activity 4 (n=29)	10	34.5	16	55.5	2	6.7	1	3.4	0	0
Activity 5 (n=13)	6	46.2	7	53.8	0	0	0	0	0	0
Activity 6 (n=34)	7	20.6	19	55.9	8	23.5	0	0	0	0
Average		36.2		46.5		14.97		2.4		0

Students Comments

About 30%

in activities 4 and 3

some of the questions were a bit confusing

I was confused

About 50%

because sometimes the mistake can happen

I am a slow learner

I saw my perfomance

It was my first time to get it n do it using computer

need more excercising

STILL LEARNING HOW TO BE GOOD

STILL NEED MORE ACTIVITIES

However

I understood most of the questions and what I needed to do

I understood the context and how they explained on the notes and it made it easy for me to complete the test.

About 75%
because easy to understand once you have done it
I've seen everything, but I don't know everything that was tested.
because it was understandable
because the diagram were clear and the explanations were clear too
some of the question was not clear
SOME OF THE QUESTIONS WAS NOT EASY TO UNDERSTAND
That is the percent I can reach in this topic.
The notes helped me to answer the activities.
The Quiz, Info, Notes and the video somehow made me to see Trig clearer
because I am not sure about question 4 (activity 3)
I managed to get most answers correct
it was not that much challenging
some questions I still find difficult to understand
Test was for revision that is why I can manage to pass about 70%.
according to my perfomance
I did not understand all the the question with the cosine rule
ALMOST EVERYTHING WAS EASY
IAM NOT SURE ABOUT THE ANSWER OF QUESTION 3 (activity 6)

Very well 100%
Because notes explained for me
by reading the note and watching the video I did understand the work
They gave me a full explanation about the whole content
It was easy to do
it was understandable
I revised some of the stuff at home yesterday
I understand the work that I was doing because it was revision
the information, the quiz and the video was informative

d) Quiz feedback

QUIZ feedback	was not clear	was informative	was easy to follow	directed me where to study in resources	was useless
Activity 1	7 (20.6%)	13 (38.2%)	23 (67.6%)	10 (29.4%)	1 (2.9%)

Students Comments

directed me where to study in resources

it has shown me where I have forgotten and where I need to study
(blank)
was easy to follow

because we are learning about right angles
I did not ask for help from the tutors to show me how to do it
It did not give me any challenge
it is because there is a instructions before a test
IT WAS EASY TO UNDERSTAND
it went were I can easily grab it without panicking
it's easy to follow
the feedback gives you a hint or information on what you must look at
the quiz made it simple when answering the questions
(blank)
was easy to follow, directed me where to study in resources

explained very clear
guides me to study and understand to answer questions
was easy to follow, directed me where to study in resources, was useless

Like I said...all of it remind me of a long time ago work
was informative

It elaborates and portray the ratios according to the sides and angles involved
They showed me where I should put more efforts.
(blank)
was informative, was easy to follow

it was very helpful
because all the diagram were show and also the labeling

it was informative and easy to follow

Many question are easy to answer and easy to understand.

(blank)

was informative, was easy to follow, directed me where to study in resources

it makes our live more interesting

it was so clear because I manage to answer these questions and I like to test myself in what I learn

(blank)

was not clear

because I did not understand those questions

I couldn't understand how I was supposed to answer

It was not easy for me to see it clearly

The quiz was not clear because even after I corrected my answers it would still tell me I had incorrect answers.

(blank)

e) How did you use the resources? (35 responses)

Good answers

1. NOTE ,I CHECKED THE EXAMPLES AND IT WAS NOT DIFFICULT TO UNDERSTAND
2. I used notes before I read test as to test myself that I have managed to understand my notes.
3. I firstly watched the video and it gave me a clue of what the activity was about
4. I USED THE RESOURCES EVERY TIME I WAS STUCK SO WOULD JUST CLICK ON THE VIDEO SO IT COULD ASSIST ME IN ANSWERING DIFFICULT PROBLEMS
5. by understanding it
6. I used the notes to get a clear understanding of what I was doing
7. the notes gave mea clue
8. I USED THEM AS A REVISION
9. the video showed each step solving the problem The notes were clear that I applied information from them
10. I used them in a good manner in such a way they brought memories to me
11. I used them to help me revise this chapter and it was really helpful
12. they helped a lot when it comes to solving problems
13. Reference
14. I LOOKED AT THEM EVERY TIME I FELT STUCK
15. I used them in calculating
16. I USED THEM TO ANSWER THE QUESTIONS
17. the notes gave me some useful detauls
18. I used the notes and the video to refresh my memory for the topic.
19. I was using videos to refresh my mind
20. when I got stuck I went there to look for the ratios and what I didn't undersstand
21. I used them to remind me of topics I forgot
22. I applied the method from the video especially on question one to question three they were really useful

Did not use

1. I didn't use it cause I have already know the topic (2)
2. I did not use it

Not good

1. it’s very interesting
2. when I got stuck I asked for help
3. correctly
4. Correctly.
5. so easy
6. by using them and apply them
7. like a boss lady
8. I used them very well
9. easy and nice
10. the note were easy to use the video was clear

f) How did you figure out what to do?

Review resources

1. by looking at the video
2. by watching a video
3. from the video.
4. I used the video as my source
5. I watched the video
6. I watched the video.
7. I applies the knowledge I got from the notes
8. I revised the notes before I started the test
9. by using notes and read the question
10. I watched the video and reed the notes
11. FROM THE NOTE AND THE VIDEOS
12. I WATCHED THE VIDEOS AND I READ THE INSTRUCTIONS

Other

1. APPLYED TH THE COSINE RULE AND USE THE FOMULA FOR SOLVING QUESTIONS
2. Analyze the question properly
3. BY LOOKING AT THE QUESTIONS AND THE DIAGRAMS
4. by noting what is asked
5. had to check the basics
6. I did it my self
7. I figure out everything by using cosine rule
8. I read the basics
9. I read the statement given and then looked at the figure given
10. just answered correctly
11. just calculated
12. just to follow the rules and apply them
13. REFRESHING MY MEMORY BASED ON THINGS I DID IN GRADE 12.
14. to practice more on that type of questions
15. to relax when I answer the questions
16. trying to answer it with own my knowledge

Asked for assistance

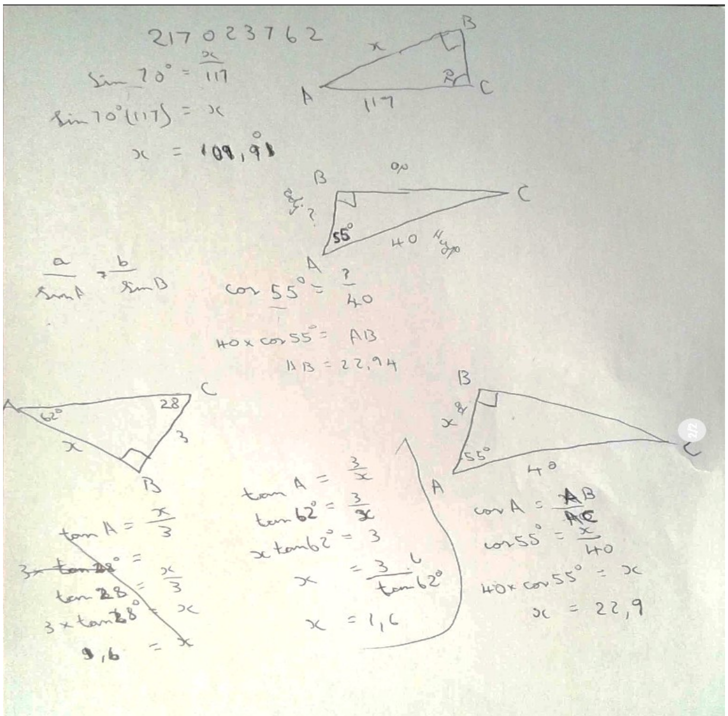
1. asked for help
2. by just following instruction or asking the tutor for help

Meaningless

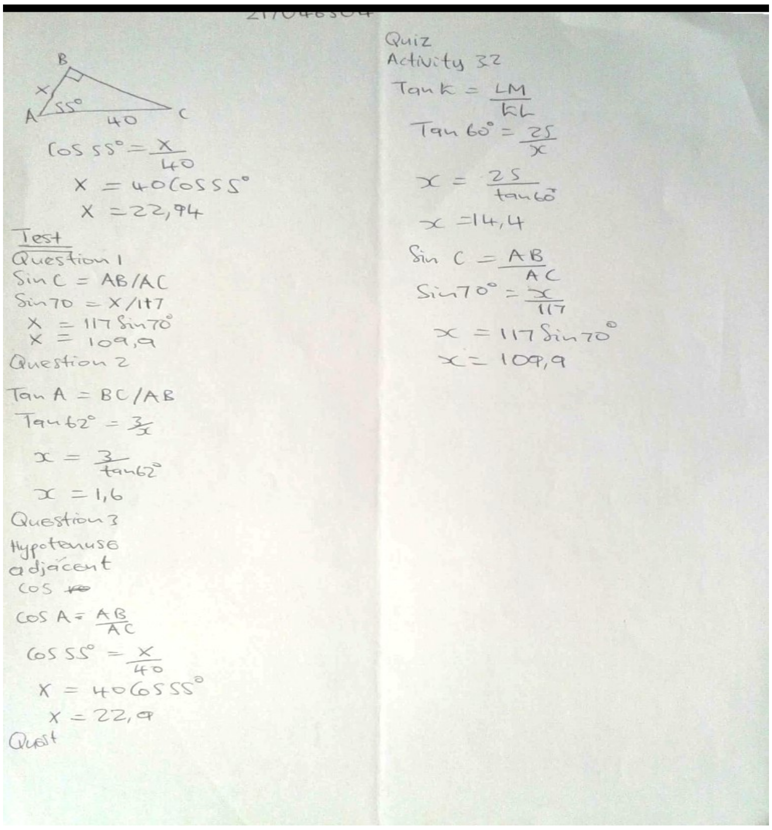
1. NULL
2. cool

Appendix 9: Examples of Students Scripts

9.1 Rough



9.2 Neat



Appendix 10: Quizlet Results

10.1 Cycle 3

Activity1

	User ID	User Score	Full Score	Passing Score	Passing Status	Post Date	Elapsed
1	1449230342963	60	90	72	Fail	2015-12-4 14:05:35	00:18:18
6	1449230961730	90	90	72	Pass	2015-12-4 14:15:40	00:05:17
26	1449641708104	90	90	72	Pass	2015-12-9 08:20:56	00:05:38
37	1449641708104	90	90	72	Pass	2015-12-9 08:20:56	00:05:38
47	1457092154620	60	90	72	Fail	2016-3-4 14:05:06	00:14:06

48	1457092154620	60	90	72	Fail	2016-3-4 14:05:06	00:14:06
11	1457093291792	40	90	72	Fail	2016-3-4 14:52:53	00:44:12
5	1457093337326	60	90	72	Fail	2016-3-4 14:31:32	00:22:27
4	1457093471746	90	90	72	Pass	2016-3-4 14:29:10	00:17:55
12	1457093724836	50	90	72	Fail	2016-3-4 15:05:30	00:49:38
9	1457093795012	70	90	72	Fail	2016-3-4 14:38:54	00:18:26
3	1457093940975	80	90	72	Pass	2016-3-4 14:29:40	00:24:52
2	1457094064574	80	90	72	Pass	2016-3-4 14:27:50	00:16:20
13	1457094263633	60	90	72	Fail	2016-3-4 15:08:48	00:43:25
7	1457094457097	90	90	72	Pass	2016-3-4 14:38:56	00:11:09
8	1457094840397	90	90	72	Pass	2016-3-4 14:39:23	00:05:08
10	1457094966683	60	90	72	Fail	2016-3-4 14:48:54	00:18:46
14	1457097653239	70	90	72	Fail	2016-3-4 15:28:18	00:07:10
15	1457098353197	90	90	72	Pass	2016-3-4 15:36:05	00:03:28
16	1457098760254	90	90	72	Pass	2016-3-4 15:49:49	00:10:11
22	1457419905061	50	90	72	Fail	2016-3-8 09:28:05	00:30:02

17	1457420023910	60	90	72	Fail	2016-3-8 09:06:08	00:10:11
19	1457420102516	50	90	72	Fail	2016-3-8 09:16:59	00:21:53
20	1457420242431	80	90	72	Pass	2016-3-8 09:17:21	00:17:18
23	1457420274322	50	90	72	Fail	2016-3-8 09:34:37	00:33:28
21	1457420934021	90	90	72	Pass	2016-3-8 09:23:01	00:11:49
18	1457420946507	90	90	72	Pass	2016-3-8 09:15:44	00:06:11
24	1457421459551	60	90	72	Fail	2016-3-8 09:39:23	00:21:28
25	1457422829238	80	90	72	Pass	2016-3-8 09:57:30	00:16:58
36	1457422829238	80	90	72	Pass	2016-3-8 09:57:30	00:16:58
28	1457504198900	60	90	72	Fail	2016-3-9 08:54:21	00:37:20
39	1457504198900	60	90	72	Fail	2016-3-9 08:54:21	00:37:20
27	1457504561921	50	90	72	Fail	2016-3-9 08:41:08	00:18:16
38	1457504561921	50	90	72	Fail	2016-3-9 08:41:08	00:18:16
30	1457505778732	50	90	72	Fail	2016-3-9 09:08:31	00:25:21
41	1457505778732	50	90	72	Fail	2016-3-9 09:08:31	00:25:21
29	1457506183914	90	90	72	Pass	2016-3-9 08:58:19	00:08:23

40	1457506183914	90	90	72	Pass	2016-3-9 08:58:19	00:08:23
31	1457506277917	80	90	72	Pass	2016-3-9 09:06:30	00:15:06
42	1457506277917	80	90	72	Pass	2016-3-9 09:06:30	00:15:06
32	1457507282735	80	90	72	Pass	2016-3-9 09:13:57	00:05:38
43	1457507282735	80	90	72	Pass	2016-3-9 09:13:57	00:05:38
33	1457507923317	80	90	72	Pass	2016-3-9 09:32:00	00:12:59
44	1457507923317	80	90	72	Pass	2016-3-9 09:32:00	00:12:59
34	1457508067426	70	90	72	Fail	2016-3-9 09:34:31	00:12:12
45	1457508067426	70	90	72	Fail	2016-3-9 09:34:31	00:12:12
35	1457508785094	90	90	72	Pass	2016-3-9 09:41:39	00:08:30
46	1457508785094	90	90	72	Pass	2016-3-9 09:41:39	00:08:30

Activity2

	User ID	User Score	Full Score	Passing Score	Passing Status	Post Date	Elapsed
1	1457347188920	20	60	19.8	Pass	2016-3-7 12:40:03	00:00:14
2	1457942061143	20	60	19.8	Pass	2016-3-14 09:54:46	00:00:21
3	1458116744475	20	60	19.8	Pass	2016-3-16 10:26:15	00:00:28

4	1457509522101	40	60	19.8	Pass	2016-3-9 09:46:31	00:01:24
5	1458116385007	20	60	19.8	Pass	2016-3-16 10:21:13	00:01:24
6	1457508186167	60	60	19.8	Pass	2016-3-9 09:24:33	00:01:27
7	1457508677111	20	60	19.8	Pass	2016-3-9 09:33:27	00:01:59
8	1458116210283	20	60	19.8	Pass	2016-3-16 10:19:17	00:02:16
9	1457698778521	20	60	19.8	Pass	2016-3-11 14:22:02	00:02:17
10	1458115170284	20	60	19.8	Pass	2016-3-16 10:01:52	00:02:21
11	1457941885970	20	60	19.8	Pass	2016-3-14 09:53:54	00:02:28
12	1457503285306	20	60	19.8	Pass	2016-3-9 08:05:37	00:04:11
13	1457505184514	20	60	19.8	Pass	2016-3-9 08:37:30	00:04:25
14	1457509563689	20	60	19.8	Pass	2016-3-9 09:50:39	00:04:35
15	1457505983353	20	60	19.8	Pass	2016-3-9 08:51:21	00:04:58
16	1457505983353	20	60	19.8	Pass	2016-3-9 08:51:21	00:04:58
17	1457504772740	20	60	19.8	Pass	2016-3-9 08:31:23	00:05:10
18	1457508932593	20	60	19.8	Pass	2016-3-9 09:41:26	00:05:54
19	1457504882861	20	60	19.8	Pass	2016-3-9 08:34:11	00:06:08

20	1457509797481	20	60	19.8	Pass	2016-3-9 09:56:38	00:06:40
21	1458116381193	20	60	19.8	Pass	2016-3-16 10:26:25	00:06:42
22	1457941556547	20	60	19.8	Pass	2016-3-14 09:53:12	00:07:16
23	1449644128001	20	60	19.8	Pass	2015-12-9 08:58:33	00:08:45
24	1458108800321	20	60	19.8	Pass	2016-3-16 08:27:06	00:13:45
25	1457507179204	40	60	19.8	Pass	2016-3-9 09:21:58	00:15:39
26	1457506754275	20	60	19.8	Pass	2016-3-9 09:22:48	00:23:34

Activity3

	User ID	User Score	Full Score	Passing Score	Passing Status	Post Date	Elapsed
1	1458221127682	0	90	29.7	Fail	2016-3-17 15:26:39	00:01:07
2	1457506875083	30	90	29.7	Pass	2016-3-9 09:07:09	00:05:54
3	1458108744892	0	90	29.7	Fail	2016-3-16 08:19:01	00:06:36
4	1458115358212	20	90	29.7	Fail	2016-3-16 10:13:56	00:11:18
5	1450080095902	30	90	29.7	Pass	2015-12-14 10:04:17	00:13:44
6	1457698313346	50	90	29.7	Pass	2016-3-11 14:28:57	00:17:03
7	1457698246341	50	90	29.7	Pass	2016-3-11 14:29:37	00:18:50
8	1457697805484	50	90	29.7	Pass	2016-3-11 14:28:32	00:25:07

Activity5

	User ID	User Score	Full Score	Passing Score	Passing Status	Post Date	Elapsed
1	1458116189401	40	40	13.2	Pass	2016-3-16 10:19:30	00:03:01
2	1450252468947	40	40	13.2	Pass	2015-12-16 09:59:06	00:04:37
3	1450248007399	40	40	13.2	Pass	2015-12-16 08:45:49	00:05:42
4	1458109934396	40	40	13.2	Pass	2016-3-16 08:40:22	00:08:07
5	1450246506145	40	40	13.2	Pass	2015-12-16 08:24:13	00:09:07
6	1458115484618	40	40	13.2	Pass	2016-3-16 10:14:53	00:10:09
7	1458303103721	30	40	13.2	Pass	2016-3-18 14:22:28	00:10:44
8	1458303103721	30	40	13.2	Pass	2016-3-18 14:22:28	00:10:44
9	1458294724051	40	40	13.2	Pass	2016-3-18 12:05:45	00:13:41
10	1457942115593	40	40	13.2	Pass	2016-3-14 10:18:59	00:23:44
11	1458108743457	40	40	13.2	Pass	2016-3-16 09:24:18	01:11:55

10.2 Cycle 4

Activity1

	User ID	User Score	Full Score	Passing Score	Passing Status	Post Date	Elapsed
1	1486199205554	70	90	72	Fail	2017-2-4 11:44:19	00:25:44
3	1487841153620	60	90	72	Fail	2017-2-23 11:34:53	00:15:33

4	14878412084666	60	90	72	Fail	2017-2-23 11:28:18	00:12:36
5	14878412084666	60	90	72	Fail	2017-2-23 11:28:18	00:12:36
6	14878412104257	70	90	72	Fail	2017-2-23 11:59:44	00:36:39
7	14878412104416	60	90	72	Fail	2017-2-23 11:37:25	00:14:10
10	14878412151697	70	90	72	Fail	2017-2-23 11:48:49	00:25:36
11	14878412160196	60	90	72	Fail	2017-2-23 11:43:23	00:27:57
12	14878412161806	60	90	72	Fail	2017-2-23 11:35:00	00:19:43
13	14878412162566	60	90	72	Fail	2017-2-23 11:28:45	00:09:46
14	14878412178427	70	90	72	Fail	2017-2-23 11:56:37	00:31:06
15	14878412186697	70	90	72	Fail	2017-2-23 11:50:08	00:34:42
16	14878412187966	60	90	72	Fail	2017-2-23 11:37:59	00:13:57
17	14878412198936	60	90	72	Fail	2017-2-23 11:30:37	00:11:40
18	14878412209917	70	90	72	Fail	2017-2-23 11:54:10	00:26:21
19	14878412245796	60	90	72	Fail	2017-2-23 11:43:39	00:18:12
20	14878413180544	40	90	72	Fail	2017-2-23 11:51:38	00:36:15
24	14878425711925	50	90	72	Fail	2017-2-23 11:42:39	00:06:10
25	14878427636717	70	90	72	Fail	2017-2-23 11:48:18	00:20:30
26	14878427679505	50	90	72	Fail	2017-2-23 11:42:17	00:12:27
35	14878432461996	60	90	72	Fail	2017-2-23 11:59:04	00:05:27
39	14878434916116	60	90	72	Fail	2017-2-23 12:22:46	00:30:26
40	14878436302947	70	90	72	Fail	2017-2-23 12:01:27	00:19:04
2	14862015825599	90	90	72	Pass	2017-2-4 11:56:17	00:09:52
8	14878412132758	80	90	72	Pass	2017-2-23 12:01:27	00:07:37
9	14878412142339	90	90	72	Pass	2017-2-23 11:33:49	00:09:39
21	14878413463008	80	90	72	Pass	2017-2-23 11:56:50	00:40:45
22	14878423531298	80	90	72	Pass	2017-2-23 11:40:20	00:07:42
23	14878425407348	80	90	72	Pass	2017-2-23 11:50:06	00:14:00
27	14878428087198	80	90	72	Pass	2017-2-23 11:48:52	00:10:13
28	14878428088209	90	90	72	Pass	2017-2-23 11:52:53	00:12:41
29	14878430412418	80	90	72	Pass	2017-2-23 11:55:58	00:11:52
30	14878430471909	90	90	72	Pass	2017-2-23 11:50:50	00:06:33
31	14878430846809	90	90	72	Pass	2017-2-23 11:49:22	00:04:35
32	14878431246059	90	90	72	Pass	2017-2-23 11:52:08	00:06:39

33	1487843205045	90	90	72	Pass	2017-2-23 11:53:00	00:05:48
34	1487843234714	90	90	72	Pass	2017-2-23 11:52:53	00:05:04
36	1487843353525	90	90	72	Pass	2017-2-23 11:53:46	00:04:30
37	1487843465836	90	90	72	Pass	2017-2-23 11:59:16	00:08:03
38	1487843469887	90	90	72	Pass	2017-2-23 11:54:56	00:03:33
41	1487843737433	90	90	72	Pass	2017-2-23 12:04:02	00:08:20
42	1487843740657	90	90	72	Pass	2017-2-23 12:01:40	00:05:52
43	1487843795264	90	90	72	Pass	2017-2-23 12:02:34	00:04:45
44	1487844003246	90	90	72	Pass	2017-2-23 12:04:53	00:04:23
45	1487844003246	90	90	72	Pass	2017-2-23 12:04:53	00:04:23
46	1487844063308	90	90	72	Pass	2017-2-23 12:09:16	00:08:07
47	1487845569223	80	90	72	Pass	2017-2-23 12:39:45	00:13:27
48	1487848067243	90	90	72	Pass	2017-2-23 13:17:47	00:09:58
49	1488197316747	80	90	72	Pass	2017-2-27 14:16:29	00:06:56

Activity2

	User ID	User Score	Full Score	Passing Score	Passing Status	Post Date	Elapsed
1	1487849876710	20	60	19.8	Pass	2017-2-23 13:41:01	00:03:05
2	1487849894277	20	60	19.8	Pass	2017-2-23 13:45:22	00:07:08
3	1487849897275	20	60	19.8	Pass	2017-2-23 13:46:11	00:07:54
4	1487849901530	20	60	19.8	Pass	2017-2-23 13:46:11	00:07:50
5	1487849962013	20	60	19.8	Pass	2017-2-23 13:49:07	00:09:44
6	1487849970425	20	60	19.8	Pass	2017-2-23 13:48:49	00:09:18
7	1487849973587	20	60	19.8	Pass	2017-2-23 13:41:31	00:01:57
8	1487850003155	20	60	19.8	Pass	2017-2-23 13:45:31	00:05:27
9	1487850086397	20	60	19.8	Pass	2017-2-23 13:50:19	00:08:52
10	1487850096074	20	60	19.8	Pass	2017-2-23 13:44:20	00:02:44
11	1487850153231	20	60	19.8	Pass	2017-2-23 13:50:42	00:08:09
12	1487850158981	20	60	19.8	Pass	2017-2-23 13:46:57	00:04:17
13	1487850194977	20	60	19.8	Pass	2017-2-23 13:55:08	00:11:53
14	1487850220983	20	60	19.8	Pass	2017-2-23 13:46:54	00:03:13

15	1487850226115	20	60	19.8	Pass	2017-2-23 13:49:28	00:05:42
16	1487850226115	20	60	19.8	Pass	2017-2-23 13:49:28	00:05:42
17	1487850303544	20	60	19.8	Pass	2017-2-23 13:50:07	00:05:03
18	1487850360209	20	60	19.8	Pass	2017-2-23 13:51:36	00:05:36
19	1487850448891	20	60	19.8	Pass	2017-2-23 13:48:13	00:00:34
20	1487850556141	20	60	19.8	Pass	2017-2-23 13:50:42	00:00:48
21	1487850734022	20	60	19.8	Pass	2017-2-23 13:52:32	00:00:1
22	1487850795336	20	60	19.8	Pass	2017-2-23 13:59:13	00:05:49
23	1487850909753	20	60	19.8	Pass	2017-2-23 13:58:16	00:02:56
24	1487851180876	20	60	19.8	Pass	2017-2-23 14:00:39	00:00:35
25	1487851225097	20	60	19.8	Pass	2017-2-23 14:03:03	00:02:38
26	1487924345244	20	60	19.8	Pass	2017-2-24 10:22:19	00:03:1
27	1487925081130	20	60	19.8	Pass	2017-2-24 10:31:50	00:00:29

Activity3

	User ID	User Score	Full Score	Passing Score	Passing Status	Post Date	Elapsed
2	1487917994238	20	90	29.7	Fail	2017-2-24 08:43:09	00:09:55
6	1487918029385	20	90	29.7	Fail	2017-2-24 08:48:18	00:14:28
7	1487918029385	20	90	29.7	Fail	2017-2-24 08:48:18	00:14:28
8	1487918761140	20	90	29.7	Fail	2017-2-24 08:48:29	00:02:23
10	1487918940641	20	90	29.7	Fail	2017-2-24 08:51:31	00:02:27
12	1487919135632	20	90	29.7	Fail	2017-2-24 08:53:10	00:00:52
14	1487919252502	10	90	29.7	Fail	2017-2-24 08:54:50	00:00:32
1	1487918000087	30	90	29.7	Pass	2017-2-24 08:42:48	00:09:28
3	1487917883665	30	90	29.7	Pass	2017-2-24 08:44:16	00:12:52
4	1487917991155	30	90	29.7	Pass	2017-2-24 08:46:07	00:12:55
5	1486276670711	30	90	29.7	Pass	2017-2-5 08:40:46	00:02:51
9	1487918315856	40	90	29.7	Pass	2017-2-24 08:49:13	00:10:37
11	1487918563176	40	90	29.7	Pass	2017-2-24 08:53:21	00:10:37
13	1487918671246	40	90	29.7	Pass	2017-2-24 08:54:18	00:09:45
15	1487918761781	60	90	29.7	Pass	2017-2-24 08:56:15	00:14:07

16	1487919121236	30	90	29.7	Pass	2017-2-24 08:59:02	00:07:00
17	1487919958667	40	90	29.7	Pass	2017-2-24 09:07:19	00:04:31
18	1487919726590	30	90	29.7	Pass	2017-2-24 09:08:37	00:06:27
19	1487920446909	30	90	29.7	Pass	2017-2-24 09:19:18	00:04:58
20	1487920800616	30	90	29.7	Pass	2017-2-24 09:21:53	00:01:52
21	1487920815952	30	90	29.7	Pass	2017-2-24 09:22:42	00:02:25
22	1487920289271	30	90	29.7	Pass	2017-2-24 09:22:13	00:10:43
23	1487921561637	30	90	29.7	Pass	2017-2-24 09:33:41	00:00:57
24	1487921667495	40	90	29.7	Pass	2017-2-24 09:35:57	00:01:18

Activity 5

	User ID	User Score	Full Score	Passing Score	Passing Status	Post Date	Elapsed
	1487923580217	40	40	13.2	Pass	2017-2-24 10:20:20	00:14:00
1	1488196030197	40	40	13.2	Pass	2017-2-27 13:53:50	00:06:40
2	1488196227078	40	40	13.2	Pass	2017-2-27 13:58:48	00:08:21
3	1488196223739	40	40	13.2	Pass	2017-2-27 13:58:57	00:08:33
4	1488196238346	40	40	13.2	Pass	2017-2-27 13:59:03	00:08:25
5	1488196149236	40	40	13.2	Pass	2017-2-27 13:59:27	00:10:18
6	1488196634186	40	40	13.2	Pass	2017-2-27 13:59:11	00:01:57
7	1488196097287	30	40	13.2	Pass	2017-2-27 14:02:29	00:14:12
8	1488196223063	40	40	13.2	Pass	2017-2-27 14:04:36	00:14:13
9	1488196291115	40	40	13.2	Pass	2017-2-27 14:07:03	00:15:32
10	1488197069608	40	40	13.2	Pass	2017-2-27 14:09:44	00:05:15
11	1488196977093	40	40	13.2	Pass	2017-2-27 14:09:48	00:06:51
12	1488197102583	40	40	13.2	Pass	2017-2-27 14:09:43	00:04:40
13	1488196417076	30	40	13.2	Pass	2017-2-27 14:10:59	00:17:22
14	1488196076391	40	40	13.2	Pass	2017-2-27 14:11:48	00:23:51
15	1488196796186	40	40	13.2	Pass	2017-2-27 14:12:32	00:12:36
16	1488196484464	40	40	13.2	Pass	2017-2-27 14:13:59	00:19:14
17	1488197605830	40	40	13.2	Pass	2017-2-27 14:15:58	00:02:33
18	1488197604768	40	40	13.2	Pass	2017-2-27 14:16:42	00:03:18

19	1488197590706	40	40	13.2	Pass	2017-2-27 14:16:38	00:03:27
20	1488197726699	40	40	13.2	Pass	2017-2-27 14:17:20	00:01:54
21	1488196263390	40	40	13.2	Pass	2017-2-27 14:19:20	00:28:16
22	1488197902340	40	40	13.2	Pass	2017-2-27 14:19:36	00:01:14
23	1488197960485	40	40	13.2	Pass	2017-2-27 14:20:40	00:01:19
24	1488197952809	40	40	13.2	Pass	2017-2-27 14:20:33	00:01:20
25	1488196138725	40	40	13.2	Pass	2017-2-27 14:21:30	00:32:31
26	1488196433512	40	40	13.2	Pass	2017-2-27 14:21:16	00:27:22
28	1488198117211	40	40	13.2	Pass	2017-2-27 14:22:55	00:00:58
29	1488198164069	40	40	13.2	Pass	2017-2-27 14:23:50	00:01:06
30	1488198195915	40	40	13.2	Pass	2017-2-27 14:23:54	00:00:38
31	1488196402170	40	40	13.2	Pass	2017-2-27 14:25:25	00:32:03

Activity 6

	User ID	User Score	Full Score	Passing Score	Passing Status	Post Date	Elapsed
1	1488198892273	10	40	28.8	Fail	2017-2-27 15:12:37	00:36:13
2	1488199960342	20	40	28.8	Fail	2017-2-27 14:56:25	00:03:41
4	1488536476646	20	40	28.8	Fail	2017-3-3 12:33:01	00:10:26
6	1488536539395	20	40	28.8	Fail	2017-3-3 12:42:47	00:17:34
7	1488536600974	20	40	28.8	Fail	2017-3-3 12:45:31	00:18:25
8	1488538133223	0	40	28.8	Fail	2017-3-3 12:52:36	00:04:
9	1488539348624	20	40	28.8	Fail	2017-3-3 13:14:41	00:05:26
10	1489046191520	20	40	28.8	Fail	2017-3-9 10:07:32	00:10:59
13	1489146486895	0	40	28.8	Fail	2017-3-10 14:22:40	00:09:39
3	1488536376897	30	40	28.8	Pass	2017-3-3 12:32:00	00:12:14
5	1488536548693	30	40	28.8	Pass	2017-3-3 12:34:39	00:12:
11	1489047680440	30	40	28.8	Pass	2017-3-9 10:27:41	00:06:18
12	1489147665727	30	40	28.8	Pass	2017-3-10 14:12:51	00:05:00

Appendix 11: Student Profile

11.1 Cycle 1

Gender	Frequency	%
Male	19	51.4%
Female	18	48.6%
	37	

Age	Frequency	%
<18	5	13.5%
18-20	19	51.4%
21-23	8	21.6%
24-26	3	8.1%
26>	1	2.7%
	37	

Matric year	Frequency	%
Previous year	19	51.4%
One year before	6	16.2%
Two year before	6	16.2%
More than two year	6	16.2%
	37	

Computer experience	Frequency	%
Novice/Beginner	12	30.6%
Intermediate	22	61.1%
Expert user	3	8.3%

	37	

11.2 Cycle 2

Gender	Frequency	%
Male	19	51.4%
Female	18	48.6%
	37	

Age	Frequency	%
<18	5	13.5%
18-20	19	51.4%
21-23	8	21.6%
24-26	3	8.1%
26>	1	2.7%
	37	

Matric year	Frequency	%
Previous year	19	51.4%
One year before	6	16.2%
Two year before	6	16.2%
More than two year	6	16.2%
	37	

Computer experience	Frequency	%
Novice/Beginner	12	30.6%
Intermediate	22	61.1%

Expert user	3	8.3%
	37	

11.3 Cycle 3

Gender	Frequency	%
Male	20	52.6
Female	18	47.4
	38	

Age	Frequency	%
<18	5	13.2
18-20	19	50
21-23	9	23.7
24-26	3	7.4
26>	1	2.6
	38	

Matric year	Frequency	%
Previous year	19	50
One year before	7	18.4
Two years before	6	15.8
More than two years	6	15.8
	38	

Computer experience	Frequency	%
Novice/Beginner	11	29

Intermediate	24	63
Expert user	3	8
	38	

11.4 Cycle 4

Gender	Frequency	%
Male	30	83.3%
Female	6	16.7%
36	36	

Age	Frequency	%
<18	6	16.7%
18-20	18	50.0%
21-23	12	33.3%
24-26	0	0%
26>	0	0%
	36	

Matric year	Frequency	%
Previous year	24	66.7%
One year before	8	22.2%
Two year before	1	2.8%
More than two year	3	8.3%
	36	

Computer experience	Frequency	%

Novice/Beginner	17	47.2%
Intermediate	14	38.9%
Expert user	5	13.9%
	36	