DESIGN OF A PROTOTYPE MOBILE APPLICATION TO MAKE MATHEMATICS EDUCATION MORE REALISTIC

Dawid B. Jordaan, Dorothy J. Laubscher and A. Seugnet Blignaut
TELIT-SA, North-West University, Vanderbijlpark Campus, South Africa

ABSTRACT

To enter the world of work, students require skills which include flexibility, critical thinking, problem solving, collaboration and communication. The use of mobile technologies which are specifically created for a context could stimulate motivation in students to recognise the relevance of Mathematics in the real world. South Africa in particular is a suitable location to use mobile learning across distance due to its viability, affordability and availability as opposed to web-based technology. The design team developed an app for financial Mathematics based on the principles of realistic mathematics education (RME) for mathematics teachers to use with their students. The paper describes the design process and general usability aspects of the formative evaluation of the prototype app for financial Mathematics. The authors suggest that a graphic artist becomes part of the design team to enhance the visual attractiveness of the app.

1. INTRODUCTION

The rapidly changing information society influences the roles of learners and teachers (Gravemeijer, 2012). Future jobs require what Gravemeijer (2012) refers to as 21st century skills, which include "flexibility, critical thinking, problem solving, collaboration, and communication." Gravemeijer (2012) emphasizes the importance of addressing these demands by investigating educational practices that may nurture these goals. Heck et al. (2007) are of the opinion that the use of mobile technology could increase motivation as well as performance in learners. Also, the use of real-life contexts stimulate motivation because the relevance of Mathematics can be seen in the real world (Risnawati et al., 2014).

Various reasons are offered for poor performance in Mathematics, which include: when topics are taught (Fauzan et al., 2013), inaccurate learning material, inadequate or outdated teaching methods, poor forms of assessment, students' anxiety about Mathematics (Widjaja and Heck, 2003); and students' negative attitudes towards Mathematics (Widjaja and Heck, 2003).

Mobile learning is a field that is rapidly expanding and it affords new possibilities to improve learning, especially in a distance education (DE) environment (Kizito, 2012). South Africa in particular is a suitable location to use mobile learning in distance education due to its viability and affordability as opposed to web-based technology (Kizito, 2012). The portability of mobile technology allows learners to work creatively and collaboratively (Zaranis et al., 2013). When used correctly, technology could promote critical thinking, improve problem solving skills and facilitate collaboration (Stols, 2012). Further research is required to determine how the mobile phone can effectively be used in testing in DE (Kizito, 2012).

This paper investigates the need for, and the design and development of, a mobile application which would assist Mathematics teacher-students in making their teaching, as well as their students' learning more realistic in terms of the context in which the learning takes place.

2. LITERATURE REVIEW

2.1 Realistic Mathematics Education

Mathematics teachers are challenged to develop Mathematics education that is in line with the dynamic conceptions of symbolizing and the development of meaning (Bakker et al., 2003). The role of the teacher is essential to understand how to teach effectively with technology (Drijvers, 2012). Digital tasks should be designed in such a way that students are encouraged to develop their own Mathematics. The teacher should guide the process and should know when to further explore a topic or concept and when to cease to investigate a topic (Drijvers et al., 2013).

The traditional approach to teaching Mathematics still dominate in many classrooms today (Fauzan et al., 2013). This approach is characterized by teachers who actively explain material and provide examples and exercises, while learners listen, write and perform the tasks the teacher requires (Gravemeijer, 2012, Widjaja and Heck, 2003). The social norms of traditional classrooms dictate that the teachers' answers are always correct and that students should follow given procedures to reach correct answers, which are more important than reasoning (Gravemeijer, 2012). Learners seldom have the opportunity to understand the rationale behind algorithms that are taught to them (Risnawati et al., 2014). Such a traditional approach to teaching Mathematics is held responsible for the poor quality of Mathematics Education and students' negative attitude towards Mathematics (Fauzan et al., 2013, Widjaja and Heck, 2003). Another consequence of traditional teaching is that when students solve word problems, high level cognitive and metacognitive processes are often absent (Mousoulides et al., 2007).

Reform from the traditional approach demands that curricula, teaching materials and assessment need to be adapted (Zulkardi, 2000). Freudenthal (1968), often regarded as the father of Realistic Mathematics Education (RME), opposes the traditional idea that the end result of the work of mathematicians is the starting point for Mathematics Education (Gravemeijer and Doorman, 1999). RME is regarded as a domain-specific instruction theory for the teaching and learning of Mathematics (Drijvers et al., 2013). The RME-based teaching and learning process promotes learner-centred learning (Fauzan et al., 2013). Problem solving through modelling leads to the design of activities that allow for students to deal with non-routine problem situations that demand the development of important mathematical ideas which can be extended, explored and refined in other problem situations (Mousoulides et al., 2007). Technological tools create new prospects for problem solving in Mathematics (Doorman et al., 2007). A corner stone of RME is that students are encouraged to not only receive information, but also question and process information (Widjaja and Heck, 2003), actively participate in the educational process and develop mathematical tools and insights (Drijvers et al., 2013).

2.2 Mobile Learning

Mobile technology offers a new generation of learning to students of all ages without being bound by place and time (Alzaza and Yaakub, 2010). Mobile learning (mLearning) is becoming more popular within formal education as its benefits offer cost-efficiency, portability; instant connectivity; and context sensitivity. Mobile learning assists students to create social interaction; it promotes collaborative learning, interactivity and instant feedback as well as collaboration between peers; it improves their knowledge structure; their learning achievements and motivation (Mouza and Barrett-Greenly, 2015). Domingo and Gargante (2016) further point out that students are more willing to engage when learning with mobile technology; their desire to accomplish educational tasks also increases with the use of mobile technology, and it helps learners to become more self-directed in their learning. Mobile communication in education is a solution with a selection of prospects and challenges (Kommers and Hooreman, 2009).

mLearning applications have various educational benefits: they can be used as study aids; can be accessed from almost anywhere; and with the aid of location capabilities, students can use location-based information (Cheon et al., 2012). Mobile technology applications supplement higher education by extending traditional educational platforms and encouraging distance learning or using settings outside of the classroom (Al-Emran et al., 2016). Content applications that make use of personalized instruction can facilitate academic growth and self-efficacy among students (Mouza and Barrett-Greenly, 2015).

3. METHOD

This research relates to the first phase of a four-phased qualitative design-based research process where four teacher-students in the Open Distance Education (ODL) program of the North-West University (NWU), Potchefstroom Campus participated in individual interviews. They shared their perceptions and experiences on support teachers' need in order to effectively implement the RME principles in their teaching practice. The teacher-students confirmed that their own students inter alia (i) had problems with certain areas of Mathematics, (ii) suffered challenges with the integration of the content across the curriculum, (iii) were excited about the affordances that mobile learning could bring to Mathematics education, and (iv) experienced challenges to link school Mathematics to real life problems, e.g. handling their own finances. The researchers decided to zoom in on the aspect of financial Mathematics for the content aspect of the mobile application (app) because all the participants mentioned this area as troublesome to their students.

The context in which the app will be used should form the anchor for the development of the content (Widjaja and Heck, 2003). The app was specifically designed for teacher-students enrolled in an open distance learning (ODL) teacher professional development programme through the Unit of Open Distance Learning (UoDL) at the North-West University at the Potchefstroom Campus. They were all established Mathematics teachers at semi-rural schools in the North-West Province, South Africa, and enrolled for a BEd Honours programme. The design of the application was based on RME principles: (i) guided reinvention (or progressive mathematisation); (ii) emergent modelling; and (iii) didactical phenomenology (Andresen, 2007). The process of guided reinvention began with a real-life problem which was then mathematised (Gravemeijer and Doorman, 1999). The aim with the app was to guide these teacher students to become comfortable with using technology in teaching and learning, as well as to enable them to interact with their learners on RME.

3.1 Creating the App

Software engineering is the application of engineering to the design, development, implementation, testing and maintenance of software in a systematic method. The objective of software engineering is to produce software systems to customers in a cost effective way. Once installed these systems should display characteristics such as efficiency, reliability, maintainability, robustness, portability and so on (Sommerville, 2016). The software process is a set of activities and associate results which produce a software product. Software specification, development, validation and evolution are fundamental process activities common to all software processes.

Software development models are processes or methodologies used for the development of software projects. There are many development models that have been developed in order to achieve different objectives. The models specify the various stages of the process and the order in which they are carried out (Sommerville, 2016). Examples of software development models are: Evolutionary Prototyping Model; Spiral Method (SDM); Iterative and Incremental Method; Extreme programming (Agile development); Waterfall model; Prototype model; Rapid application development model and so on (Whitten and Bentley, 2007). Choosing the right model for developing a software product or application is very important as the model determine where and when the development and testing processes are carried out.

For the development of our app, which we name *Financial Maths App*, we decided to use the Prototype Model because of the advantages that this model offer: Users are actively involved in the development; Since a working model of the system is provided, the users get a better understanding of the system being developed; Errors can be detected much earlier; Rapid user feedback is available leading to better solutions; Missing functionality can be identified easily; and Confusing or difficult functions can be identified (Whitten and Bentley, 2007). The basic idea is that instead of freezing the requirements (as required by many other models) before a design or coding can proceed, a prototype is built to understand the requirements based on the currently known requirements. By using this prototype, the client can get an "actual feel" of the system, since the interactions with the prototype can enable the client to better understand the requirements of the desired system. The prototype is usually not a complete system and many of the details are not built into the prototype. The goal is to provide a system with overall functionality. Figure 1 depicts the phases in the development of a prototype.
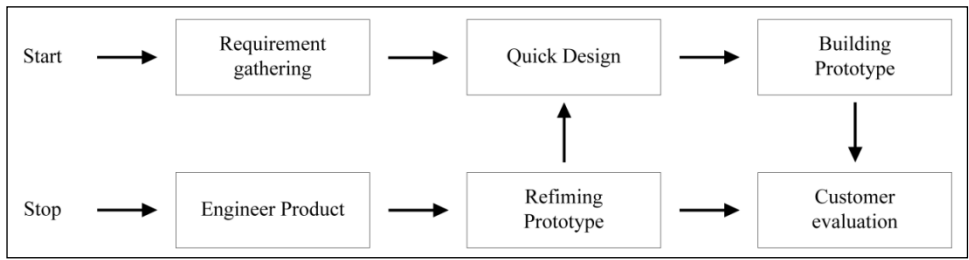
Figure 1. Prototyping model (Whitten and Bentley, 2007).

3.2 Creating the App

Background. While the first author of this paper was the designer of the app, the second author was the content specialist and also responsible for the various design documents, and the third author was the expert on the use of technology in teaching and learning. Together they formed a tight project team. They obtained ethics clearance for this research from the Ethics Committee of the North-West University (NWU-HS-2014-0267).

Requirement (Step 1). The first step in creating an app was to develop a clearly defined purpose for the mobile app: we had to determine what the app should be able to do; what its primary appeal would be; which concrete problem it was going to address; and what part of life it aimed to improve. Detail design documents were created which outlined the standards, planning design, development, and ongoing evaluation of the project (Fleisch and Schöer, 2014).

Quick Design (Step 2). Next the foundation of the user interface was laid. This step visually conceptualized the main features and a rough layout and structure of the app. Sketches for the proposed layout and structure of the app were drawn which assisted the team to understand the journey better Figure 2 is an example of such a sketch.
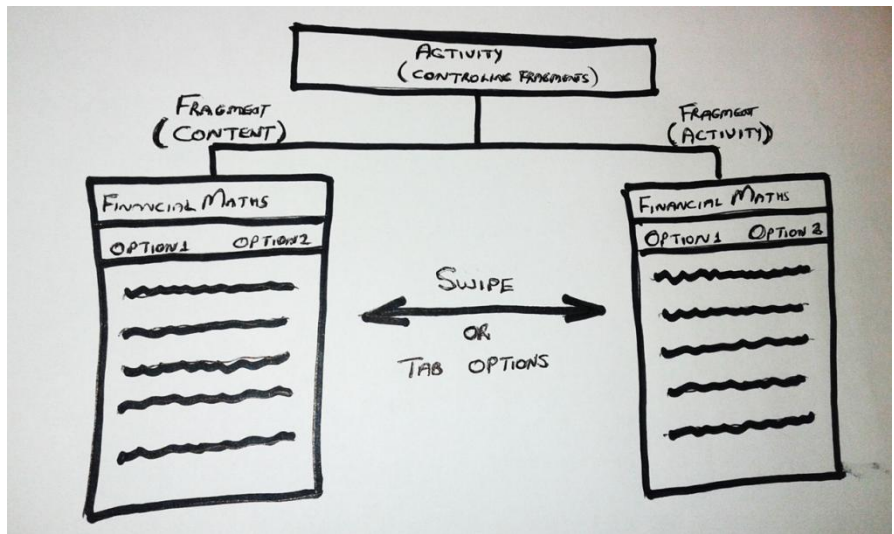

Figure 2. Example of layout sketch (own sketch).

Building Prototype (Step 3). At this stage all the ideas and features culminated as a clear picture of the structure and a storyboard for the project was created. The storyboard provided a road map which illustrated the connections between the different screens and how the user could navigate through the app. The storyboard formed the foundation for the first version of the prototype.

Customer Evaluation (Step 4). The next step involved the testing of the prototype. Friends, family, colleagues, and experts all helped to review the prototype. They were requested to test run the app and give sincere feedback and identify flaws and dead-end links. If possible to monitor how they used the app, one should take note of their actions as these would provide important feedback for user interface (UI) and user

experience (UX) evaluation (Molich and Nielsen, 1990). Based on their feedback, the prototype was modified. The aim was to finally specify the app concept before going into the design process. For the *Financial Maths app*, the content author tested the app with two of her Mathematics colleagues who are Mathematics lecturers, as well as with a RME expert.

Refining Prototype (Step 5). Next, individual screen content were designed. The task was to create high-resolution versions of the prototype. All comments from the prototype testers were included in order to design the most suitable user interface. With the screen designs completed and implemented, the actual app concept was complete, all the graphics were inserted, and all text was signed off—the actual design was now implemented and made clickable.

Repeat (Step 2 to 5). The next step was to test the full design once more and collect as much feedback as possible from a variety of users. The new ideas and comments were used to refine the app. A consistent look and feel of the layout was assured and we ensured that it would perform reliably on different devices.

Deployment (Step 6). As the vast majority of the intended students used Android devices (Dahlstrom et al., 2016), the brief was to develop the *Financial Maths app* for Android devices (smart phones and tablets). The *Financial Maths* app was consequently installed on Android devices and tested for functionality in a live environment.

4. USABILITY OF THE APP

4.1 The User Interface

Figure 1 illustrates two scenarios that are realistic and relevant to students at school, from which the concepts of simple and compound interest could develop. Students are not expected to reinvent all the content themselves, and should be guided by the teacher who allows them the opportunity to reflect on their invented strategies (Gravemeijer and Doorman, 1999). Drijvers et al. (2013) suggest that guidance from the teacher will help the progression in a sensible manner, as is suggested in Figure 3.
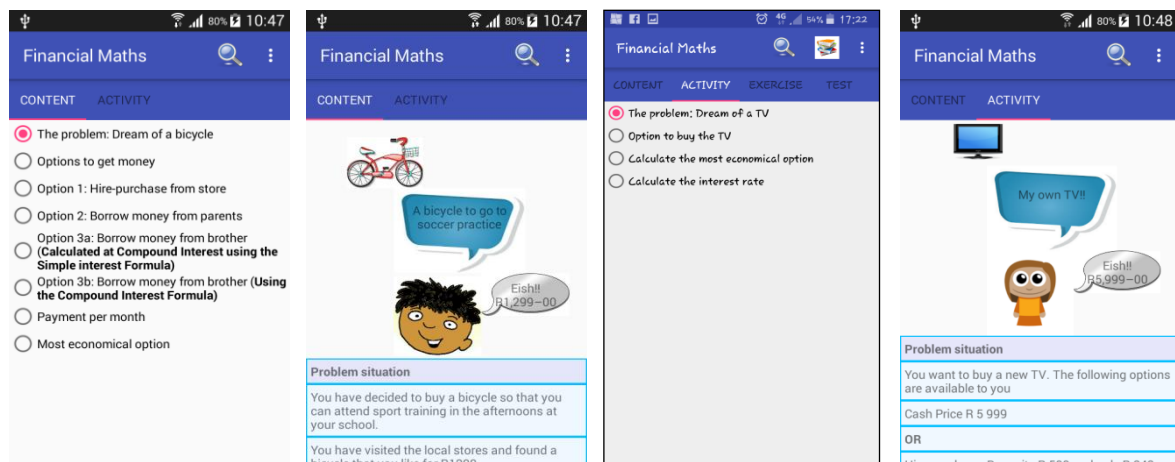

Figure 3. A context that is meaningful and natural is created.

Emergent modelling refers to the development of models from the student's activity which leads to the emergence of formal Mathematics (Gravemeijer and Doorman, 1999). The use of models is encouraged as a bridge between what is abstract to students and what is real (Dolk et al., 2002). Figure 4 illustrates how the use of models has been encouraged in the app. The models too are grounded in the contextual problem and are not derived from the intended Mathematics (Gravemeijer, 1999). The last screenshot in Figure 4 illustrates that students are in various instances given three opportunities to attempt to develop their own strategies to solve a problem before a hint is given.
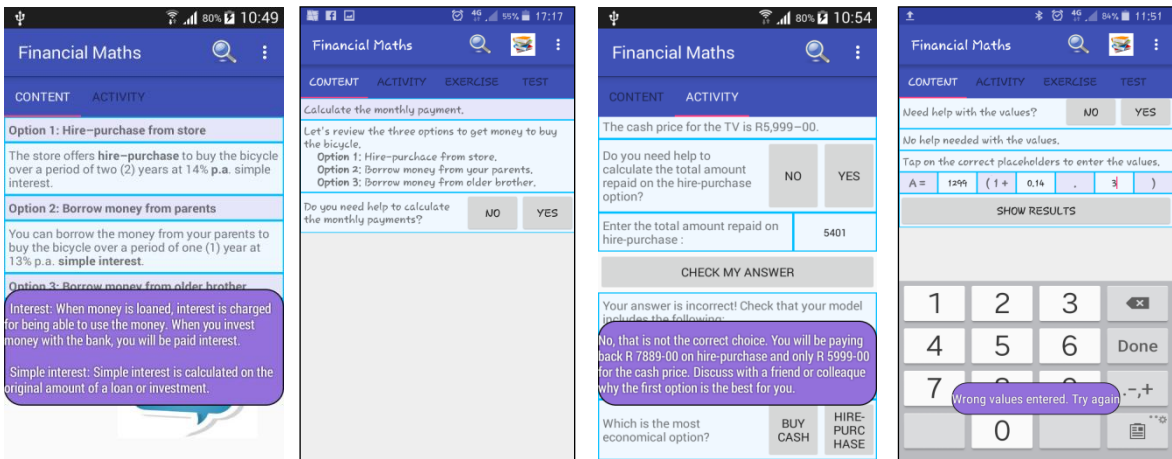
Figure 4. Hints and tips are provided should students require them.

The third principle that was incorporated in the design of the app was didactical phenomenology, which deals with the idea of how mathematical structures can assist in organising phenomena in real life (Zulkardi, 2000). Students are confronted with situations that need to be organised, and in that way students can build concepts (Bakker et al., 2003). The phenomena of personal finances, hire-purchase and interest rates are relevant real-life notions that can be structured with mathematical content (Figure 5).
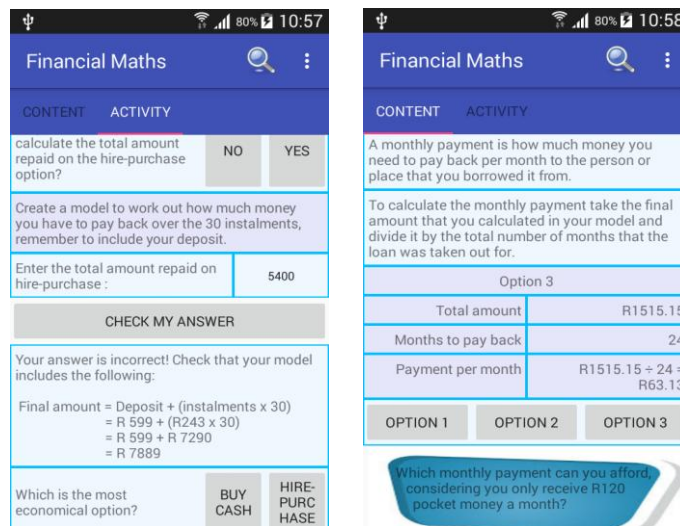

Figure 5. An illustration of the use of models.

4.2 General Usability of the App

The initial design document provided the design team with a broad idea of the content of the app. In the drafts to follow, more particulars are given with regard to the detail of when hints and tips should appear; how many attempts students can make on a solution before receiving help; and words of encouragement when the solutions are correctly worked out. Molich and Nielsen (1990) are of the opinion that general usability evaluations should comprise not more than ten members, and the design team followed this suggestion. The three team members perused and tested the first two prototypes and suggested changes in terms of usability. An RME expert evaluated the third prototype of the app and focused specifically on the inclusion of the RME principles. His evaluation revealed that all the principles of RME were sufficiently addressed in the app and that it should achieve the purpose for which it was designed, namely to make

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teachers' teaching of Mathematics, and learners' learning experiences more realistic, relevant and experientially real. He suggested that the app be thoroughly tested before being released for student use.

Two more experts in the field of Mathematics education tested the app. Their main suggestion for improving the app was to make the problem situation more visible at the start of the app:

Put something in that sets the scenario more clearly. The start of the app is too vague.

Their evaluation also included comments on why they felt the app was suited to the purpose for which it was created:

It works very well because all the steps are clearly shown. It will help the teachers to teach their learners to follow logical steps in their calculations.

The app included an activity that clearly showed the intertwining of the concepts of compound and simple interest, a key characteristic of RME (Widjaja and Heck, 2003). The Mathematics education experts found this appropriate and necessary:

I like this very much. By including this comparison of concepts you can see wow, it's quicker to use the compound interest formula, and yet you still get the same answer as when repeating the simple interest formula.

They also suggested that the app be extended to other content areas and that it be made available to a wider range of teachers.

5. CONCLUSIONS AND RECOMMENDATIONS

The design of this app has the potential to be extended into a larger project where a variety of problem content areas in Mathematics, at different grade levels, could be addressed. These apps could be made available to any Mathematics teacher who needs assistance with both content as well as the notion of incorporating relevant, real life contexts in their Mathematics teaching.

A comment made by a Mathematics education specialist relates to the need for the development of users of such apps in terms of the integration of technology into their every teaching and learning:

We had a bigger problem working the phone that doing the sums. Let's hope that the students that will be using this app are comfortable with the technology.

Although one of the points of criticism from the subject experts was that the problem scenario was not well articulated, the design team is of the opinion that a more graphic approach would work better. The context and content should be presented with the aid of more graphics and less words.

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