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MobileMath: An innovative solution to the problem of poor Mathematics performance in the Caribbean

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Given the positive research results that are appearing in the field, mobile learning is explored to determine if it can assist students in improving their performance in mathematics in secondary schools in the Caribbean. Mobile learning was expected to be motivating and offer the advantages of learning anywhere and anytime. A mobile learning system was designed comprising multiple strategies, game-based learning and personalization for learning mathematics. The mobile learning application referred to as *MobileMath* was created for learning algebra and was evaluated over a three week period with a set of secondary school students. Data collected on the usage of the mobile application as well as data from the questionnaires, pre-tests, post-tests and interviews were used to assess the effectiveness of the mobile learning application. The results reveal that the students were able to improve their performance and they were excited about using a mobile device for learning. They adapted well to using this method of learning for the first time. The students who improved were those who had done algebra in a previous school term but may have been failing the subject. However, the mobile application did not make a significant impact on students who were learning the algebraic content for the first time.

Key words: mathematics, mobile learning, Caribbean, secondary school

Introduction

Mathematics failure rates in the Caribbean are extremely high (Caribexams, 2004). Many students confess that they do not understand mathematics taught in the classroom, they do not see the significance of mathematics, and they do not like the subject. These are perhaps some of the reasons why there is a high failure rate in mathematics in the Caribbean today. The failure rate is of great concern as mathematics is a necessary subject for students to progress in further education or employment. As a result, there is a need for new learning solutions to help students improve their performance and attitudes towards mathematics. This paper discusses a research study which used mobile learning to address the problem of high failure rates in mathematics in secondary schools in Trinidad and Tobago. Mobile learning is learning which occurs with the support of mobile devices, facilitating the mobility of the learner and decreasing location limitations of learning.

In this study, secondary school students were exposed to a learning method which gave them control and flexibility when learning. These are both necessary factors for Caribbean students who are studying an average of eight subjects at the Ordinary Level. A mobile learning application called *MobileMath* was created with the aim of improving mathematics skills. The students were excited to use the *MobileMath* application and their performance improved after using the application.

Background and justification

In Trinidad and Tobago, students often express their frustration with mathematics. The Caribbean Examinations Council (CXC) examination results endorse this statement and show how poorly students have been performing over the years. On average, 41% of the students of the Caribbean passed CXC mathematics over the period 2004–2009. The CXC examination consists of two papers. Paper 1 is a multiple choice examination where most of the questions are repeated year after year therefore allowing students to memorize the questions. Paper 2, the written paper, examines more in-depth knowledge of the curriculum than the multiple choice paper. On average 63% of the students over the period 2004–2009 passed Paper 1. However during this time 22% of the students on average passed Paper 2, which indicates that most students do not understand a large portion of the mathematics curriculum (Caribexams, 2004). Table 1 illustrates pass rates from 2004–2009 (CXC 2007, CXC 2008a, CXC 2008b) and highlights that, at most, 47% of the students in any year passed mathematics.

Table 1. CXC pass rates: Mathematics

Year	Total % of Students Achieving Grade I-III
	Overall
2009	45%
2008	47%
2007	34%
2006	35%
2005	39%
2004	46%

A survey conducted as part of the *MobileMath* evaluation study with over 125 students revealed that 36% of the students admitted that they have problems with mathematics. Nineteen percent of them stated that the majority of the time they did not understand mathematics taught in class while 25% said they never understood mathematics. These statistics offer proof that students have problems with mathematics in Trinidad and Tobago and this is likely to be the case in other Caribbean countries where similar teaching and assessing methods are used.

There are many explanations for the problem of high failure rates in mathematics. Students may not always be able to complete the required curriculum on time; students have multiple intelligences, according to Gardner (1983) and it may be very difficult for one teacher to cater for the multiple intelligence of an entire class especially with limited time. Students, from a young age, may develop a psychological block against mathematics, caused by the myth that mathematics is difficult. Moreover, some students may have had a bad experience with mathematics in the past. In many schools there are, on average, 35 students to one teacher, resulting in some students not getting the individual attention they may require. There may also be a lack of motivation or students may have difficulty understanding secondary level mathematics as they lack the critical pre-requisites.

There have been some efforts to improve mathematics scores in secondary schools. The introduction of extra lessons in mathematics is a common method parents use to help their children improve their performance. There are also technology tools which can be used to help students improve their mathematics scores. However, these tools such as the Leapfrog Leapstar Learning Game System, Nintendo DS Personal Trainer: Math, and VTech Whiz Kid Learning System can be very costly. Parents have numerous expenses such as text books, school fees and extra lessons, and most of them may not be able to afford the extra expense of technological learning tools. Hence, one of the advantages of mobile learning is its affordability since the mobile application is expected to work on the phones the students already own. Mobile devices have become very popular in recent years. Figure 1 shows the increase of telephones and mobile phones. It illustrates that mobile phone penetration in Trinidad and Tobago has significantly increased compared to telephone usage in recent years.

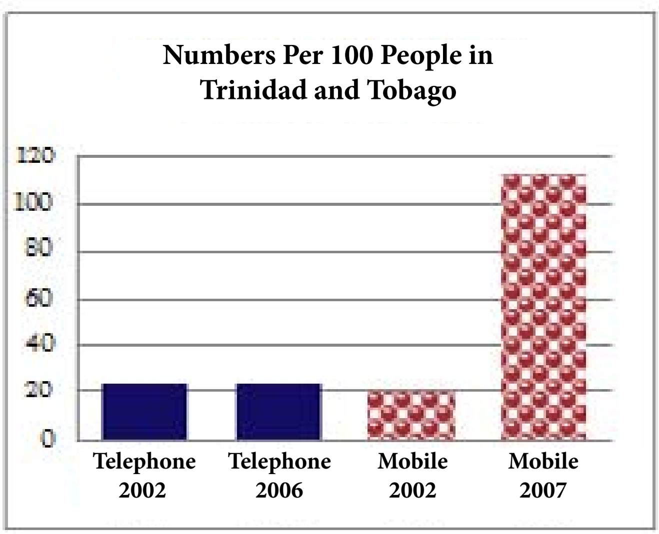

Figure 1. Telephone and mobile usage source: Mobile Active 2005

Table 2 shows that mobile subscribers in 2005 were 4.5 times greater than the number of people who owned computers and 3 times the number of internet users. The survey conducted in 2010 as part of the *MobileMath* evaluation study with over 125 students revealed that 83% of the students owned their own mobile phone and 70% agreed that they used a mobile phone seven hours or more per day calling, text messaging, playing games and browsing the Internet. This data supports the choice of using a mobile technology solution for learning in Trinidad and Tobago. Table 3 highlights several factors which justify the choice of mobile learning for mathematics.

Table 2. Statistics on Trinidad and Tobago. Source: Mobile Active (2005)

Trinidad and Tobago	
Total Population	1M
Urban Population (% of total population)	76
Adult Literacy Rate (% ages 15 years and older)	98
Mobile Subscribers (per 1000 people)	369
Internet Usage (per 1000 people)	114
Personal Computers (per 1000 people)	79
Telephone Main Lines (per 1000 people)	249
Price Basket for Mobile (US$ per month)	$7.8
Price Basket for Internet (US$ per month)	$13.4

The main goals of *MobileMath* were to:

1. determine if mobile learning can be used to help students improve their performance in mathematics
2. establish if students are motivated to use mobile learning
3. find out if game-based learning on a mobile phone is supportive and motivating in learning mathematics

Table 3. Justification for using mobile learning

Context	Reason
Ubiquitous	Mobile devices in Trinidad and Tobago are everywhere. Almost every person has at least one mobile phone.
Infrastructure available	The infrastructure is available in Trinidad and Tobago providing mobile phone coverage throughout the country, even in rural areas.
Affordability	Over the years mobile phone and calling rates have become quite affordable due to improvements in technology and the competing brands.
Mobility	The mobile phone allows people to stay in contact with each other from anywhere. The phone can give the user a sense of assurance since it provides a safety line to the outside world.
Appealing to the target group (secondary school students)	Young people find mobile devices fascinating. Most of them own a mobile phone by the time they start secondary school and even before that.
Mobility for learning	This is especially suitable for students in Trinidad and Tobago as most of them are studying on average eight subjects. This results in these students having little time for anything else but study. The mobility of learning makes it possible for the learner to learn anytime and anywhere.
A widespread target device	The application was designed to work on any mobile device with J2ME (a Java platform mobile devices) capability. Many common mobile phones use J2ME.

Literature review

Many researchers have reported successful attempts at mobile learning in various disciplines. Attewell (2005) one of the pioneers in the field of mobile learning, reported that it assisted students in building their self-esteem and self-confidence with technology. Naismith and Corlett (2006) identified some positive outcomes of mobile learning projects such as motivation, engagement and collaboration. Stead (2005) pointed out that mobile learning was able to reach places that other methods of learning could not, it was a bridge to Information Technology and it was suitable for collaboration and communication. Faux et al. (2006) reported that the students' literacy improved after using mobile learning. McFarlane, Roche and Triggs (2007) reported that students were motivated and improved their self-esteem after successfully using mobile learning. These projects identify many advantages of using mobile learning.

Valk, Rashid and Elder (2010) conducted a review of several mobile learning studies in developing countries. These studies used Short Message Service (SMS) for learning mathematics and English. Their review paper gives an idea of the results of some mobile learning studies. Two of these studies reported increases in scores, while two others were inconclusive. Other studies such as Attewell (2005) and Symbian Tweet (2010) reported that the students' motivations increased when using mobile learning. MoMath is a mobile mathematics study which used mobile devices for learning mathematics in South Africa. Results of the study indicated that the use of the mobile devices increased retention and motivation and there were improvements in students' end of term tests scores (Symbian Tweet, 2010).

Project K-Nect (2008) used mobile devices to help students increase their mathematics skills. Franklin and Peng (2008) presented another mobile learning study for learning mathematics in which iPods were used to help middle school students learn algebraic equations. In this study, videos were used to support learning beyond the hours of the classroom. This study showed that the use of iPods was viable in this middle school.

Barker, Krull and Mallinson (2005), Trifonova and Ronchetti (2003) and Koole (2006) identified problems with mobile learning such as small screen, low bandwidth, processing capabilities and lack of teacher control. They also suggested that mobile learning was not suitable for all areas of learning. However, a look at mobile devices on the market in the last ten years shows that such features have improved significantly. These studies suggest that mobile learning can assist students to improve their performance in mathematics.

Design and implementation

A mobile application called *MobileMath* was created to test the hypothesis that mobile learning can help students to improve their performance in mathematics. The system consists of the mobile phones, a server and an Internet connection. *MobileMath* connects to the server to send data for each student based on their usage. The system uses several learning strategies, game-based learning, and personalization to support the learning process. The strategies are Lessons, Examples, Tutorials, Quizzes and Fun Facts. Figure 3 is a screenshot of one of the games and Figure 4 is a screenshot of an example. The interested reader can refer to Kalloo and Mohan (2011a) for more details.

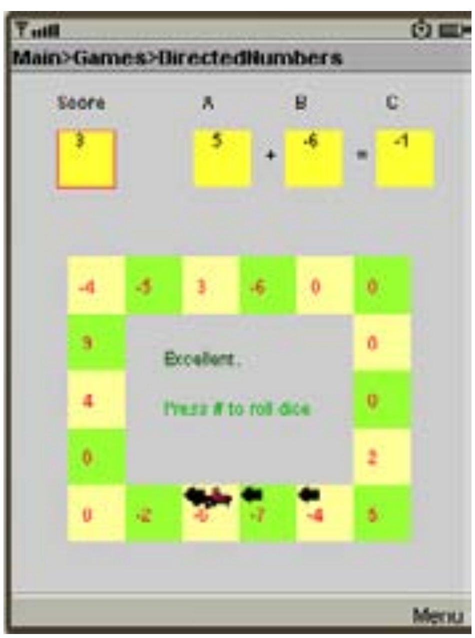

Figure 3. Games feature

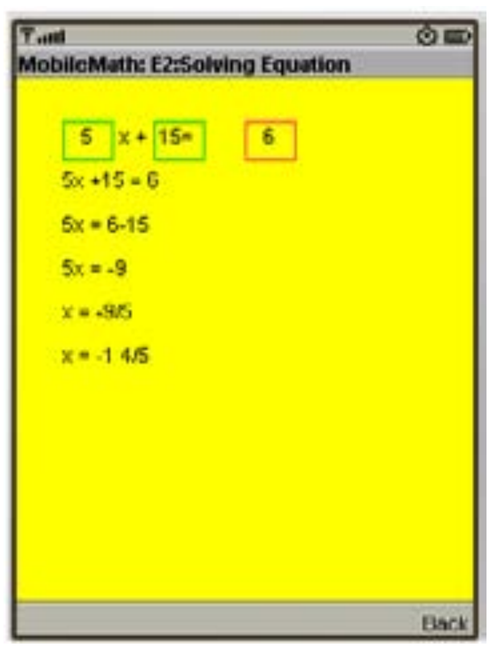

Figure 4. Examples feature

The *Lesson* describes the main concepts of a topic. The *Example* feature offers dynamic examples of mathematical problems based on the topic. The *Tutorial* is a learning activity which demonstrates the main concept, displays an example and then presents a problem for the student to work on. The *Quiz* is the main form of assessment and consists of a series of multiple choice questions based on the topic. The *Games* were created to encourage the player to practice certain mathematical skills. Hence, as students play the games and progressively get better, they improve their skill. It was expected that if the learner found the game to be fun then he or she could be learning without even knowing it.

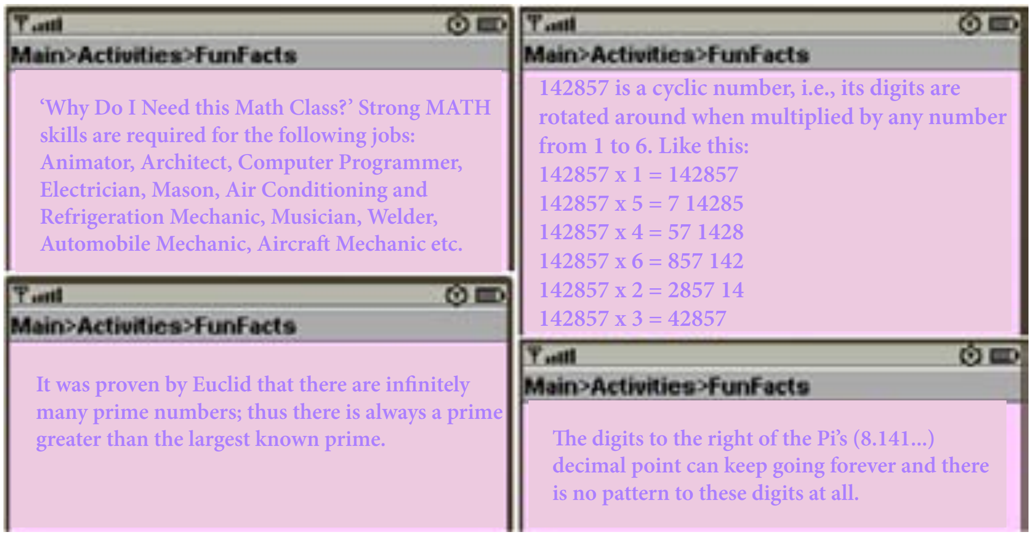

Figure 5. Fun Fact feature

The *Fun Fact* feature is a text-based activity created to highlight interesting examples of the uses of mathematics. Figure 5 shows four screenshots of some of the *Fun Facts* feature of *MobileMath*.

The application was designed with several learning activities to give the learner alternative methods of learning such as *Lessons, Examples* and *Games*. Consequently, if a learner did not understand the topic after using one feature, he or she had alternative methods to choose from. The multiple features provided were also able to address some of the different learning styles, for example visual and tactile styles.

The features were designed based on strategies derived from teaching mathematics traditionally in the classroom in Trinidad and Tobago. For instance the *Examples* feature was based on the fact that studying examples of mathematical problems was a successful method of learning mathematics. The *Games* feature was based on practicing mathematical skills learned; this is another strategy employed in the classroom by many teachers.

In Trinidad and Tobago students often complain to teachers that they do not understand why they have to learn mathematics in school. The *Fun Facts* feature was created targeting these students with the intention to creatively demonstrate uses and benefits of mathematics using riddles and stories of great mathematicians.

Some features were created to provide experiential learning as suggested by Kebritchi and Hirumi (2008) where learners can be engaged by direct experience. For instance, the *Game* feature was created where the student uses mathematics skills while playing. The *Example* was created to be dynamic so that the student could learn interactively; as the user changes the numbers the example adapts and shows the solution and working.

The mobile application was based on algebra, since this is reported to be one of the most difficult topics in Trinidad and Tobago. The idea is that if mobile learning can be shown to be successful with one of the most difficult topics in the syllabus then perhaps it can work for the other topics in mathematics. The application was based on the curriculum topic *Introduction to Algebra* with sub-topics such as *Directed Numbers, Factorization* and *Solving Equations*.

Evaluation studies

Three evaluation studies were conducted to determine the effectiveness of the mobile learning application. In total, 57 students used the mobile learning application. In the first study, the students used mobile learning without encouragement or interference from the teacher. In the second study, support and encouragement were provided by the teacher, in the form of text messages and classroom meetings. The students of Study 1 and Study 2 had been taught algebra in a previous term at school and used mobile learning to determine if their performance would improve. The students of Study 3 learned algebra for the first time during the study. They were taught in the classroom and used mobile learning as a support tool to augment their study of algebra. The objective of Study 3 was to determine how mobile learning would impact on students who were learning algebra for the first time. This study consisted of an experimental group and a control group. Pre-tests and post-tests were conducted to evaluate if there were any differences in student performance and questionnaires were completed in order to gauge students' opinions of the different features of the mobile learning application.

It was first intended to conduct the evaluation studies within some of the secondary schools in Trinidad and Tobago. However, after several attempts it was determined that many schools were unwilling to allow mobile devices on their compound. This was as a result of the misuse of mobile phones in some schools by a few students and thus rules were implemented which restricted the entry of mobile devices on school compounds. This created a challenge for the evaluation of *MobileMath*; however it was eventually solved by sourcing students from within the public schools but conducting the evaluation at a venue outside the schools.

Since the target students who participated in the evaluation study were from different geographical locations and schools, they were not familiar with each other. This did not hinder the general results of the evaluation studies as students from different schools and locations still study the same academic curriculum. However, collaboration was not an easy learning strategy to use within this group as they were unfamiliar with each other. A Bluetooth game was included as part of the mobile application. This game allowed the students to connect wirelessly via Bluetooth and play a game competing against each other within a 10 meter range. However since the students were unfamiliar with each other, it was not used. In the future, this feature of the mobile learning application will be tested by students from the same school so that they will more likely be inclined to collaborate with their peers.

Since the most commonly owned device used by this target group was the mobile phone, the application was created to work on a popular mobile phone such as the Nokia 5130. Hence each student participating in the evaluation study was given what was considered a common mobile phone for young persons in Trinidad and Tobago.

The main purpose of these studies was to evaluate mobile learning for mathematics. Ideally this could have been done by just installing the software on a mobile device with no General Packet Radio Service (GPRS) or calling minutes. However it was recognized that the students would more likely use it if the mobile application was running on the mobile phone which they used regularly, so this situation was simulated. An unlimited GPRS connection was provided with each mobile phone. There were two reasons for this. One was to not place any limits on how much data was sent to the server since the data was sent via the GPRS connection. The second reason was to allow the students to connect with each other via their mobile devices. The long-term goal of *MobileMath* is for the students to use the mobile application on their own mobile phone in their spare time. It was considered important that the students of the evaluation studies perceived the mobile devices given to them as a normal working phone. As a result, the students were given 100 free calling minutes in order for them to use the mobile device as a regular phone and not just for learning.

Results and discussion

The overall results for Studies 1 and 2 were favorable towards using mobile learning for mathematics. However, the third study was unclear and requires follow-up to confirm the results. The pre-test and post-test were analyzed using 2-tailed significant t-test. The analysis revealed that there was a significant difference between pre-test and post-test scores of both Study 1 and Study 2; however, there was no difference for the data of Study 3. Figure 6 shows the number of students who passed (students who scored 50% or more) in Study 1 and Study 2. More details can be found in Kalloo and Mohan (2011b). It illustrates that for Study 1, the students who passed increased from 9 to 14 and for Study 2 it increased from 2 to 7.

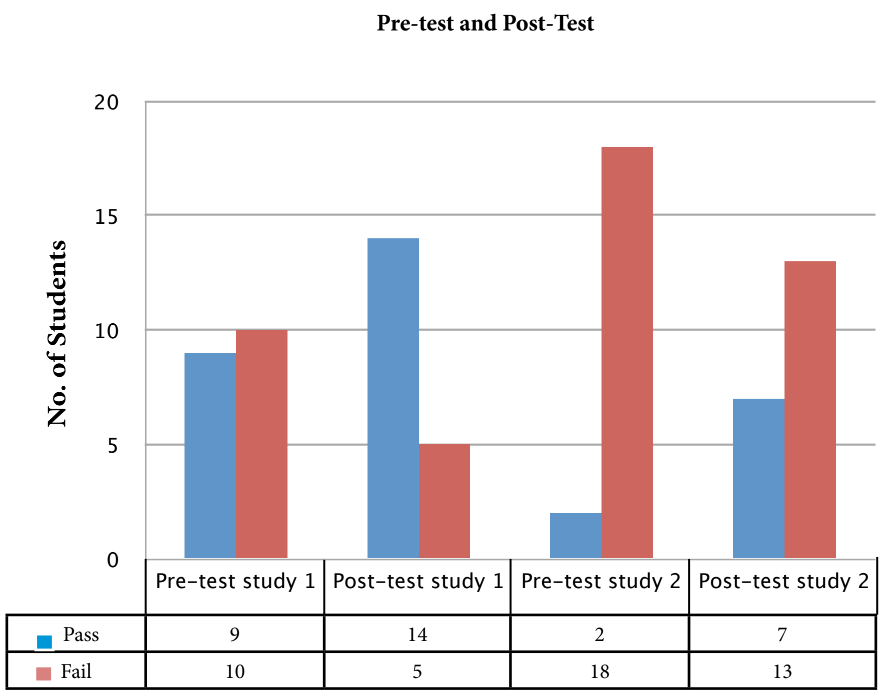

Figure 6. Number of students who passed and failed

Table 4 gives the statistical data for Studies 1 and 2 (Kalloo & Mohan, 2011b). It illustrates that students of Studies 1 and 2 improved performance by an average of 8.8% and 10.2 %, respectively. Study 3 however, did not attain any such improvements (Kalloo & Mohan, 2011a).

Table 4. Study 1 and Study 2

	Study 1	**Study 2**
Average % Increase	8.8%	10.2%
Duration	14.4 hours	58 hours
Frequency	514	861

The students used the application for a significant amount of time and there were many indications that the more the students used the mobile application the more likely they were to improve their performance. Figure 7 shows the number of times each feature was used by the students of all three studies. It highlights the fact that the students used the *Games* feature the most.

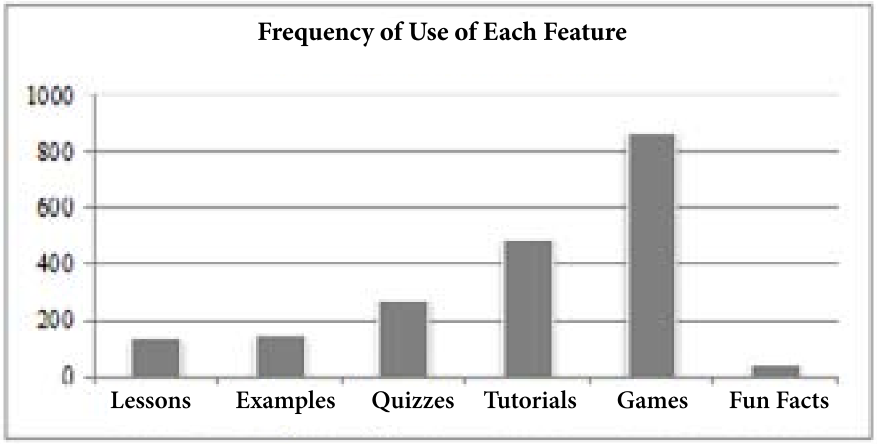

Figure 7. Number of times the students of all 3 studies used each feature

The questionnaire data supports the data in Figure 8 since 68% of the students either agreed or strongly agreed that they enjoyed the learning games more than the other learning activities. Figure 8, derived from the questionnaire data, reveals that at least 80% of all the students thought that the application helped them improve their mathematics skills, it was easy to use, and it was useful to be able to learn anytime and anywhere.

As mentioned before, Valk, Rashid and Elder (2010) have analyzed the results of several mobile learning studies. Two of these studies reported increases in scores, while two others were inconclusive. The studies conducted with *MobileMath*, support the analysis given in Valk, Rashid and Elder (2010). Valk, Rashid and Elder's (2010) results presented statistical evidence that the students improved performance and they responded positively to using mobile learning. Valk, Rashid and Elder (2010) also point out that there is a lack of analysis of mobile learning studies conducted in developing countries. However, the *MobileMath* study presents an in-depth statistical analysis of the results obtained from its evaluation.

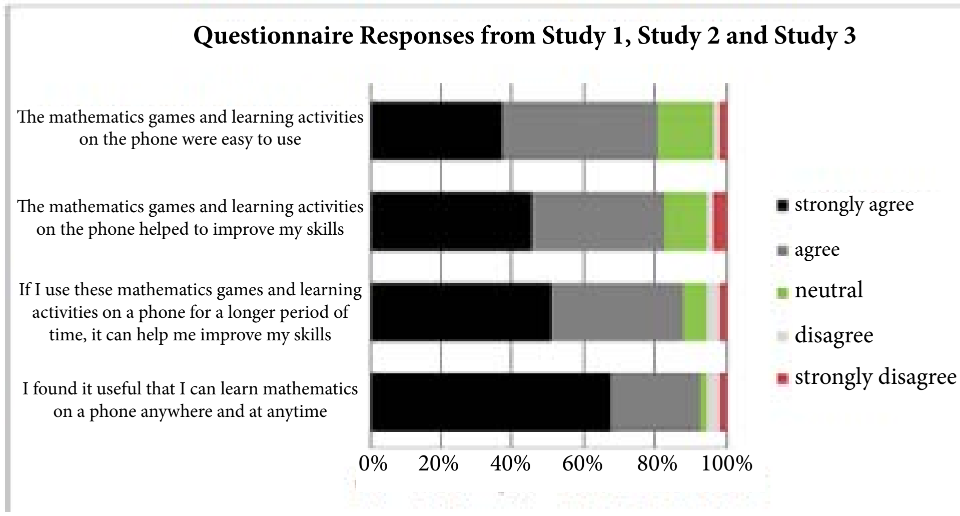

Figure 8. Questionnaire responses

The following are some guidelines suggested for using mobile learning in the Caribbean based on our experience from the *MobileMath* study:

1. Mobile learning should be used after students are taught the main concepts in the classroom.
2. Mobile learning should be used to complement the teacher and not as a standalone teaching tool.
3. Multiple strategies should be offered so that the learner has options.
4. Games should be included in mobile learning where possible since most students find them appealing.
5. *MobileMath* remains independent of the teacher, so that learners can choose to use it at their own pace.
6. Teacher support should be offered to encourage the learner to use the application.
7. The support of the schools is necessary so that students are able to use it on the compound especially for collaboration with their peers. This can provide more opportunity for collaborative activities like the Bluetooth games.
8. The mobile application should be available to learners on their own mobile devices.

Conclusion and future research

This paper discussed the *MobileMath* system which was developed and evaluated in Trinidad and Tobago to explore the effectiveness of different strategies for learning algebra on a mobile phone. A mobile learning system was created to evaluate the effectiveness of learning mathematics in one Caribbean context and three evaluation studies were conducted. The results revealed that the students of Studies 1 and 2 increased performance. This increase in performance is believed to be significant considering this was attained by the use of an innovative, inexpensive method of learning. The results indicate that this method of learning can be potentially useful for secondary school students in Trinidad and Tobago.

The next stage of the research is being planned to improve the features available in *MobileMath* to motivate and encourage students to improve. The *Games feature* was the most used and enjoyed. So, future research into creating even more motivating and fun learning games should be explored. Further research as a follow-up to Study 3 (where there was no difference in performance) can determine if mobile learning should be used for students learning algebra for the first time. Another project that can be undertaken is extending the functionality of *MobileMath* to cover the entire CXC mathematics syllabus. This would take some effort as creating the games at this stage is a tedious process since each one is uniquely based on a different mathematics skill. However, if the process of creating these games can be automated in some way, it may be worthwhile to extend *MobileMath* to cover the entire mathematics syllabus.

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