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Redesigning local games to stimulate pupils' interest in learning numeracy in Tanzania

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ABSTRACT

The lack of interest and negative attitude in learning mathematics have been described as one of the causes for the continue poor performance of the subject in primary schools and beyond in Tanzania. Despite several government's efforts to improve pass rate of mathematics, the use of digital games has not been well adopted. This study redesigned local games played by Tanzanian children all over the country into digital games for the aim of stimulating interest of pupils in learning numeracy skills. Three games: Ruka Kamba, Manati, and Kombolela were developed using eXtreme Programming practices and elements of game design for learning proposed by Plass et al. (2015). The developed games were piloted at Mlimani primary school with 111 pupils using direct observation and questionnaire, and 12 teachers using focus group interviews. The study found that the majority of children indicated that developed games are enjoyable, fun, and easy to play. Nonetheless, some few usability problems were identified during observation and are discussed. Similarly, teachers indicated that the developed games were pedagogical effective having content and skills necessary for improving numeracy skills both for self-learning and in the classroom. This study has demonstrated that local games can be redesigned into digital form and be used for stimulating interest of pupils in learning numeracy skills in developing countries.

Keywords: *Digital games; local games; games for learning; games for Africa; Children games*

INTRODUCTION

The lack of interest and negative attitude in learning mathematics have been described as one of the causes for the continue poor performance of the subject in primary schools and beyond in Tanzania. (Kisakali and Kuznetsov, 2015). For instance, the failure rate of mathematics was 90.8% in 2008, 93.4% in 2010, 94.2% in 2011, and 80.4% in 2014 (MoEVT, 2012; BEST, 2013, 2016). Generally, more than 80% of students who sit for the national secondary education examination do not pass mathematics in Tanzania (Sumra and Katabaro, 2016). The failure rates in mathematics in secondary schools is a result of poor foundation of numeracy skills in lower levels of education both in pre-primary and primary education. According to Education for all Global Monitoring, out of 650 million primary school age children, nearly 250 million lack basic numeracy skills in sub-Saharan Africa (UNESCO, 2015). In East Africa, almost 80% of pupils cannot do basic mathematics in the third year of primary school (UWEZO, 2011). Putting it into context, 7 in 10 standards 3 pupils complete standard 2 without being able to meet the numeracy skills standards of level 2.

It should be noted that pupils with poor performance tend to have difficulties in controlling working memory (McLean and Hitch, 1999; Andersson and Lyxell, 2007), poor phonological (Andersson and Lyxell, 2007), and difficulties in communication and language skills (Donlan *et al.*, 2007). It is clear therefore that poor numeracy skills have impact on other subjects and many aspects of pupils' academic development (Colliver, 2017). In recognizing the importance of equipping pupils with numeracy skills at the early age of their development, the government released its new Education and Training Policy in 2014 (Anderson and Sayre, 2016). The policy has introduced the compulsory early grade education for 3-5-year children for one year before being enrolled standard 1 in primary

schools. As a result, several initiatives have been directed towards developing teaching and learning materials as well as improving teachers training for early grade education.

A number of books of teaching and learning resources have been developed to support teachers in schools in order to equip pupils with the necessary numeracy skills. Many existing training programs are characterized by books with some illustrations, and classroom teaching based on symbols and diagrams (Glang *et al.*, 2005). The increased access of computers in schools as well as proliferation of mobile phones in the country have opened up new opportunities for enhancing numeracy skills for children. However, few attempts have been made to adopt and use of ICT specifically digital games as a tool for enhancing numeracy skills in Tanzania.

Playing digital games have shown to provide powerful environments for learning (Kirriemuir and McFarlane, 2004; Lieberman, 2006; Bottino *et al.*, 2007; Plass, Homer and Kinzer, 2015; Ferreira, Gouin-Vallerand and Hotte, 2016) and they motivate children to learn even those who at first were not interested in the subject matter (Lieberman, 2006; Praet and Desoete, 2014; Alfadhli and Alsumait, 2015) or perceived the content to be the most difficult to understand (Prensky, 2001).The motivational environment is created through a series of game features and activities that learners enjoy or find them interesting (Lieberman, 2006; Plass, Homer and Kinzer, 2015). The digital games can also help children improve their thinking and problem solving skills, and spatial perception and visualization skills (Lieberman, 2006).

Given these benefits, there is a need to adopt and use digital games to stimulate interest and bringing positive attitude in learning mathematics starting from early years of schooling. Generating pupils' interest in mathematics at the early years of school is likely to establish a positive attitude towards learning the subject in higher classes, and hopefully sustaining continued interest in learning mathematics (Colliver, 2017). Therefore, this study redesigned local games played by Tanzanian children all over the country into digital games aiming at stimulating pupils' interest in learning numeracy skills. The main hypothesis of this study is that:

> "The use of local developed digital games will stimulate interest and instill positive attitude towards learning mathematics for early grade pupils"

The use of local games was based on the fact that existing digital games have been developed in Western context and describe learning as it happens within those countries (Heeks, 2008) failing to match the understandings our pupils (Plass, Homer and Kinzer, 2015) and are not aligned with Tanzania curriculum. Therefore, three games: Ruka Kamba, Manati, and Kombolela were developed using eXtreme Programming practices and elements of game design for learning proposed by Plass et al. (2015). The developed games were piloted at Mlimani primary school with 111 pupils using direct observation and questionnaire, and 12 teachers using focus group interviews. This study has demonstrated that local games can be redesigned into digital form and be used for stimulating interest of pupils in learning numeracy skills in developing countries. Therefore, the findings of this study will be useful to various institutions and education authorities involved in policy formulation, development and implementation of teaching and learning resources for pre-primary and primary education in Tanzania and beyond.

LITERATURE REVIEW

In the past, digital games have been dismissed as a distraction from important activities such as learning (Kirriemuir and McFarlane, 2004; Nolan and McBride, 2013). As a result, the majority of early studies on digital games focused on the negative impacts of digital games for children (Lieberman, 2006; Connolly *et al.*, 2012). Some negative impacts of playing digital games for children reported in several studies include difficulties in regulating the amount of time spent on playing digital games (Ogletree and Drake, 2007), addiction (Griffiths and Davies, 2002), and anti-

social behavior (Nolan and McBride, 2013). Nowadays, digital games have gained popularity as a tool in enhancing teaching and learning in all levels of education. This is evident from increased revenue generated from game based learning worldwide (Heeks, 2008). According to recent Ambient Insight Research report, the revenue generated from game based learning reached $1.5 billion in 2012 with a growth rate of 8.3% and expected to reach $2.3 billion in 2017 (Adkins, 2013). The report further indicates that the most top selling are mobile games for early childhood education.

In addition, previous research has demonstrated that role of digital games to improve numeracy skills for children of different ages. For instance, Kam et al. (2009) developed digital games to improve literacy and numeracy skills and piloted in three communities in India. Initially, some of these games failed to match rural children's understanding of games as designers did not match with local and cultural context. They later improved the games after conducting contextual interviews with children and teachers. The new designed games were found to be more intuitive and engaging when piloted to rural children in India.

Ferreira et al. (2016) designed math and English digital game for tablets aimed to support self-learning for children in India. The game was offered from early grade learners to standard 12 onto an application embedded within the tablets. However, the game was not evaluated for usefulness in supporting children self-learning. Similarly, Wang, Liu, and Li (2011) developed digital game for early grade learners to access three aggregated types of Bloom cognitive processes including "remember & understand", "analyze & apply" and "evaluate". The game was validated with Ministry of Education in Taiwan using 17 units of games. The authors found that the developed games were more attractive and enabled learners to achieve improved learning performance than traditional text-based webpage learning.

Despite these few examples, the majority of existing games have been developed in the context of the Western societies and describe learning as it happens within developed countries (Heeks, 2008). Studies show that children learn better when learning occur in social and cultural context (Plass, Homer and Kinzer, 2015). In Tanzania, for instance, few attempts have been made to pilot western developed games such as those of GraphoGame in few schools in Tanzania. The GraphoGame and many other games have not been successful. One of the problems was that they were not developed in the context of Tanzania and therefore they were not aligned with the Tanzania curriculum.

Ultimately this points to the need for developing digital games that match the understandings that children in the context of Tanzania. This study redesigned local games that children used to play in their daily lives into digital games that can be played via mobile devices and computers. The main idea was that since children are more familiar with the local games that they play in their villages, they are likely to enjoy playing them in the new platform using mobile devices while stimulating their interest in learning numeracy skills.

DESIGN AND DEVELOPMENT OF DIGITAL GAMES

Game development project is difficult and poses a lot of challenges to traditional software development methods such as waterfall. One of the main challenge is its multidisciplinary nature involving more than one discipline (Godoy and Barbosa, 2010). In our case, the development team consisted of pupils, teachers, graphics designers, and developers. Moreover, some game features such as fun, which has no efficient technique that describes when this goal is achieved cannot easily be identified if traditional software development methods are used (Petrillo *et al.*, 2008).

Therefore, we adopted agile methods specifically eXtreme programming (XP) in the development of three identified local games into digital games. The process of developing games using XP practices are beyond this article and have been covered in a separate article (See Author Name, 2018). However, to ensure the developed games are enjoyable and meet learning objectives, elements for games design for learning proposed by Plass et al. (2015) were adopted. Plass et al. (2015) proposed four elements that need to be considered while developing digital games for learning. These elements include game mechanics, visual aesthetics, narrative, incentives, and musical score. The description on how each element was included in the games are discussed next.

Game mechanics

The game mechanics are set of activities repeated by the children throughout the game (Plass, Homer and Kinzer, 2015). Our games were designed in three learning levels in increasing difficulty. In each level, players have to play 5 different activities and score more than half of the marks to proceed to the next level. The activities in each level in the game are randomly set.

Visual aesthetic design

The developed digital games are supposed to keep all the content fresh in the learners' minds as they are trying to learn new concepts and avoid any possible distraction (Ardito *et al.*, 2005). In the same way, if the game is not designed carefully, it becomes unattractive, consequently content become difficult to follow (Khanana and Law, 2013). In our games, the characters were chosen resembling pupils of primary schools in terms of appearance and chose the uniforms that typical worn by many schools in Tanzania.

Narrative design

The developed digital games should challenge players to reach a goal while providing feedback on the players' progress (Lieberman, Fisk and Biely, 2009). To achieve this, the developed games should provide information for learning, connecting rules of play, characters, events, and incentives (Plass, Homer and Kinzer, 2015). In all three developed games, once players click start they are given instruction on how to play the game via voice-overs. Moreover, once one has managed to score more than 50% points of each activity, players are congratulated and informed that they are proceeding to the next level in a more challenging activity.

Incentive system

A learning game should motive children to learn through motivational elements that are part of the game activities (Plass, Homer and Kinzer, 2015). These incentive can be hearing spoken words of praise from characters, through receiving virtual items for successful completion of a task or earning some points (Lieberman, 2006). Lieberman et al. (2009) suggested that player's name can appear on the screen in order to help the player feel more special.

In our three developed games, once a player gets the right answer from the activity, there is audio feedback clapping hands as part of motivation. The star element is also added at the top of the screen showing the number of points a player has collected for each activity. On the other hand, when a player gets a wrong answer a voice-over feedback encouraging a player to try again is played. Figure 1 shows a sample of incentive mechanism provided in our designed games.

Figure 1: *Incentive and Feedback on a score board of Manati Game*

Musical score

The musical score is a background sounds that are often used to direct the player's attention to specific events when playing the game (Plass, Homer and Kinzer, 2015). Our games have smooth background music which is played through the game and stops when there is voiceover or new instructions need to provided. We have also included auditory information providing error feedback when a player makes an error when playing the game.

Content and skills

Another element which was considered during the game development is content and skills. This is the subject matter content and skills that the game is designed to teach (Plass, Homer and Kinzer, 2015). Therefore, our games were designed to teach two types of numeracy skills: counting and number identification. More specifically, Ruka kamba are designed to teach players counting while Manati and Kombolela teache players number identification. We tried to follow Kirriemuir and McFarlane (2004) suggestions that ensuring that each game concentrate on one skill rather than multiple skills.

THE DESCRIPTION OF THE DEVELOPED DIGITAL GAMES

Ruka Kamba

This is a rope jumping game where two pupils hold and swing a rope in both ends with the third pupil jumping at the middle (as indicated in Figure 2). The fourth pupil will normally count the number of jumps until a player touches the rope. This is a famous game in many villages and played in many primary schools in Tanzania.

Figure 2: *Ruka kamba game played in many schools in Tanzania*

The same concept was used to redesign the game into digital form. A player will count the number of jumps and once the jumping stops the player selects the correct number from the screen corresponding to the number of jumps. With correct answer, the player scores 1 point and for incorrect answer a player scores 0 point. If a player manages to get 5 correct answers, the player moves to the next level with more difficult counting. There are 5 different levels in this game with increasing difficulty. Figure 3 shows a new developed Ruka Kamba game.

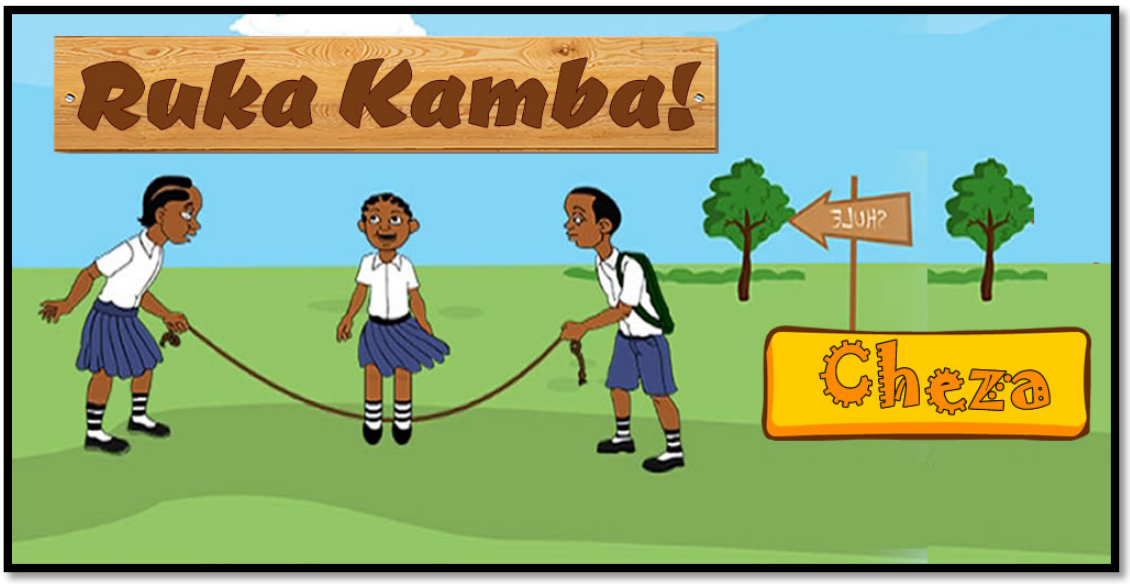

Figure 3: *A Digital Ruka Kamba Game*

Manati

This is game resembles the catapult game in terms of rules and design famously played by pupils in many villages. In fact, the older pupils tend to use Manati to hunt birds in rural areas as part of the game. The winner of this game is a pupil who managed to shoot and kill many birds per day. You need skills to be able to hit the correct target.

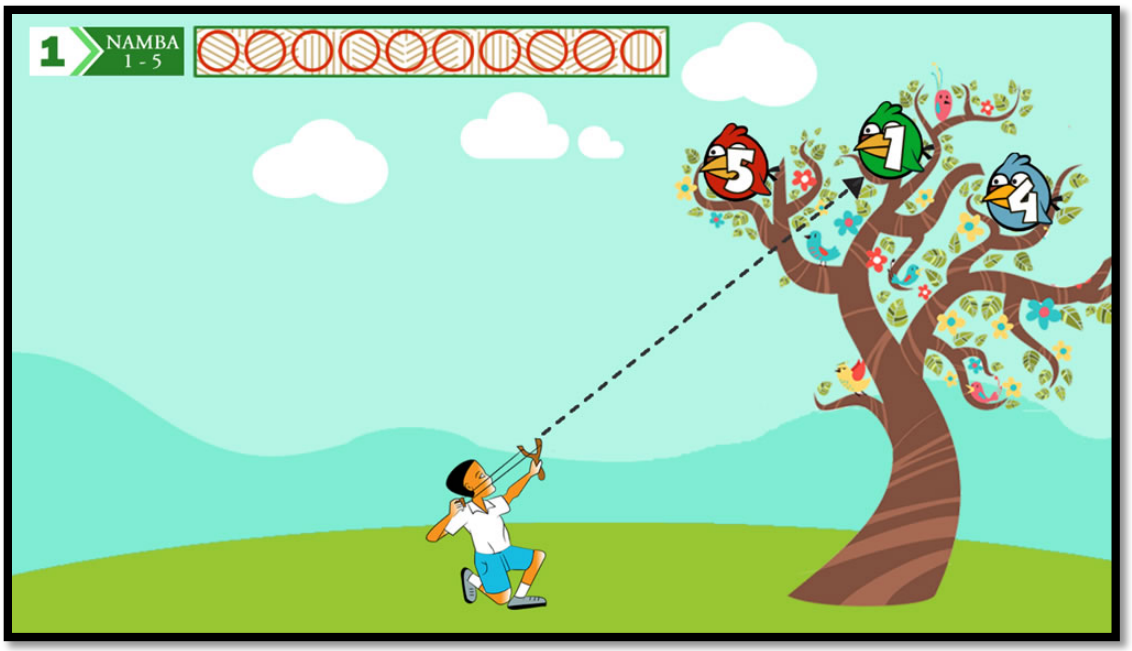

Figure 4: *A redesigned Manati game in digital form*

Kombolela

This game is similar to hide-and-seek game where one player closes eyes for a brief period while the other players hide. The seeker then opens eyes in order to try to find the hiders. The first player found is going to be the next seeker, and the last is the winner of the that round. There are many forms of hide-and- seek games depending on various context. The aim of this game was to help pupils to be able to count objects from 1 to 10. The game provides a number of hidden kids, and the player will be instructed to seek those hidden kids. If all hidden kids have been found, the player will be instructed to count them. If the player counts them correctly, the player will receive a star, followed by background sounds to congratulate a player. This game has three levels (i.e. Beginner, Intermediate and Advanced). Each level has 10 rounds of seeking hidden kids. If the player counts correctly in all 10 rounds, the game will move to the next level and adjusting the level of difficulty. Figure 5 shows a screen shot of a redesigned Kombolela game.

Figure 5: *A shows a screen shot of Kombolela game*

Uploading into Google Play

The developed games were then uploaded into Google Play Store to get more feedback and to enable many users be able to access them. In Google Play Store, the apps were named as “Manati Game”, “Ruka Kamba Game” and “Kombolela Game” to enable users be able to download.

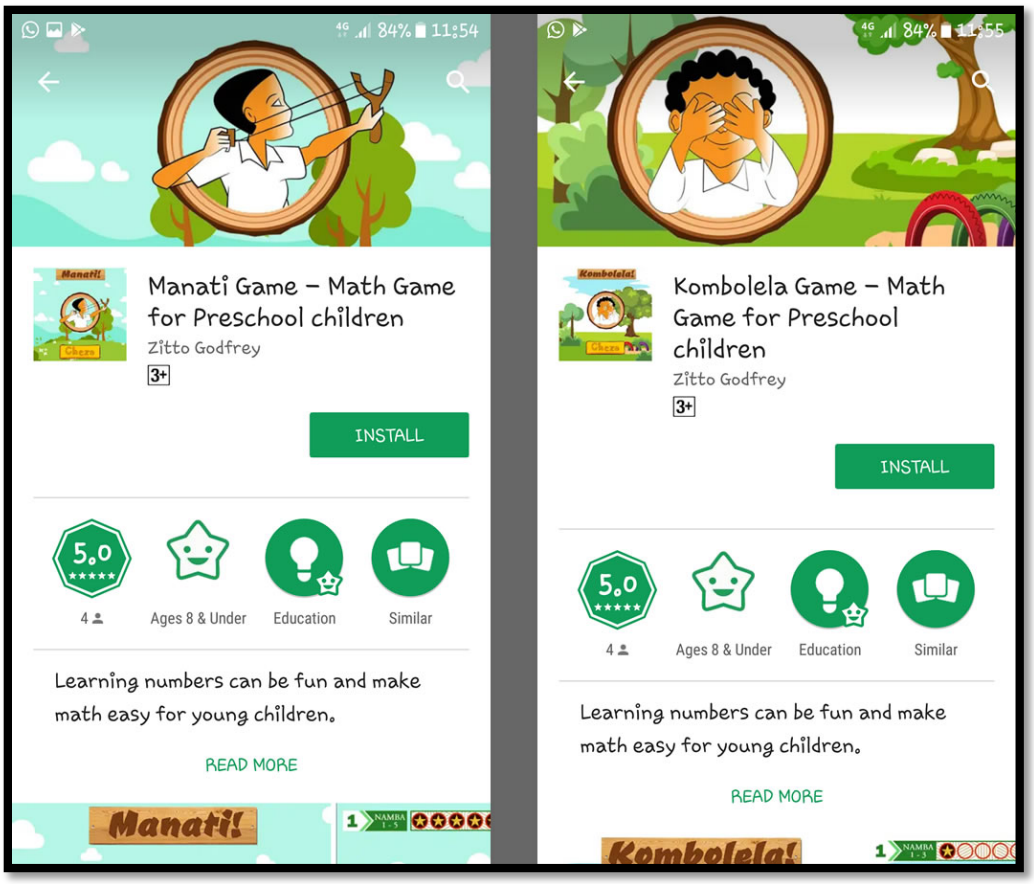

Figure 6: *Search results of Manati and Kombolela apps in a Google Play Store*

METHODOLOGY

The research employed qualitative design as a data collection method for both teachers and pupils. A total of 40 tablets were procured and loaded with games, of which 15 of them were distributed to teachers and 25 of them were distributed to pupils of Mlimani primary school in Dar es salaam. The idea was each week 25 pupils to be given tablets and test the games and then the following week another group of pupils to be given tablets making a total of 150 pupils who tested the games for six weeks. After 6 weeks, a study was conducted to elicit teachers' opinion on the usesfulness and effectivness of the developed digital games for enhancing numercy skills for pupils through focus group interview involving 12 teachers separated in three groups.

Moreover, a questionnaire was distributed to 130 pupils who played the games at least once in order to find out about the fun and enjoyment, usability, and other aspects of the game. The questionnaire was completed with the support of their teachers in the classroom environment. Of 130 returned questionnaires, 111 were completed correctly and they were usable for analysis. Of 111 pupils completed the questionnaire, 60% of pupils were 5 years old, 25% of them were 6 years old and 15% were 7 years old. Moreover, 69% of pupils were boys while 31% were girls.

Similarly, the study adopted DEVAN checklist as observation method for 20 children when they were playing games via tablets. DEVAN checklist is famous for structured and detailed analysis of video

data from user tests and uses a table to represent an interaction at multiple levels of abstraction (Vermeeren *et al.*, 2002).

FINDINGS

Easy to learn and play

A poorly designed game makes pupils spend more time in learning how to play the game rather than in mastering the knowledge provided by the game (Ardito *et al.*, 2005). Therefore, it was important to evaluate if the games were easy to play. To do it, direct observation was conducted to 20 pupils when they were playing the games, with each pupil taken to a separate room to play the game. The evaluation team was taking the videos of each pupil. The playing session took 10 minutes where a pupil starts playing a game without getting any instructions or explanations as these were meant to be self-learning games. It was estimated that a new player will take 3 minutes to complete the first level of Manati game and Ruka Kamba, and 6 minutes for Kombolela game. The new player tends to play slowly as he is trying to explore more features and understanding the objectives of the game. Usually, the estimated playing time keeps on improving as the player repeat the same level or moving to the next level.

During the playing session, it was observed that 45% of pupils who played Manati were able to complete the first level at the estimated time of 3 minutes while 32% of pupils were able to complete the first level of Ruka Kamba game at the estimated time of 3 minutes. Similarly, the study found that 80% of pupils who played Kombolela game were able to complete the first level at the estimated time of 6 minutes as shown in Figure 7.

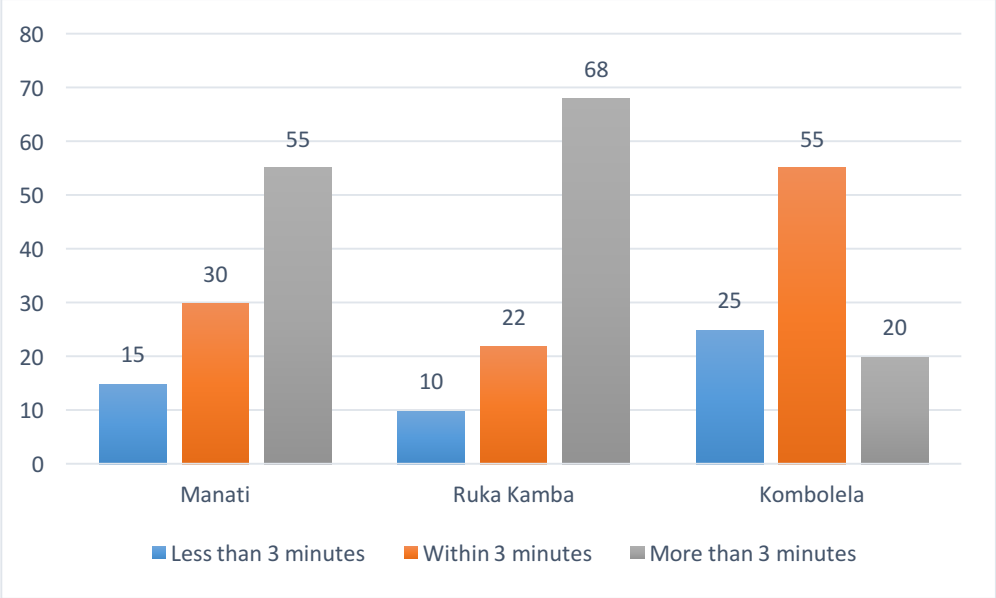

Figure 7: *Playing time for first level for three games*

The findings show that Kombolela game was ease to play compared to the other two games. Moreover, it was observed that the slingshot movements in Manati game were not smoothly

enough, also the shooting positions were very limited compared to children's expectation, hence it was taking more time to shoot birds on the tree.

After 10 minutes the pupil was told the playing session was over, but that the player could choose to continue playing the game for another two minutes or return to the class. If the pupil chose to continue playing, the session was stopped after extra two minutes. The findings indicate that many pupils requested to continue Kombolela game followed by Manati and Ruka Kamba in that order as shown in Figure 8. The seems possible that the Kombolela game and Manati and Ruka Kamba were the most easy to play and enjoyable.

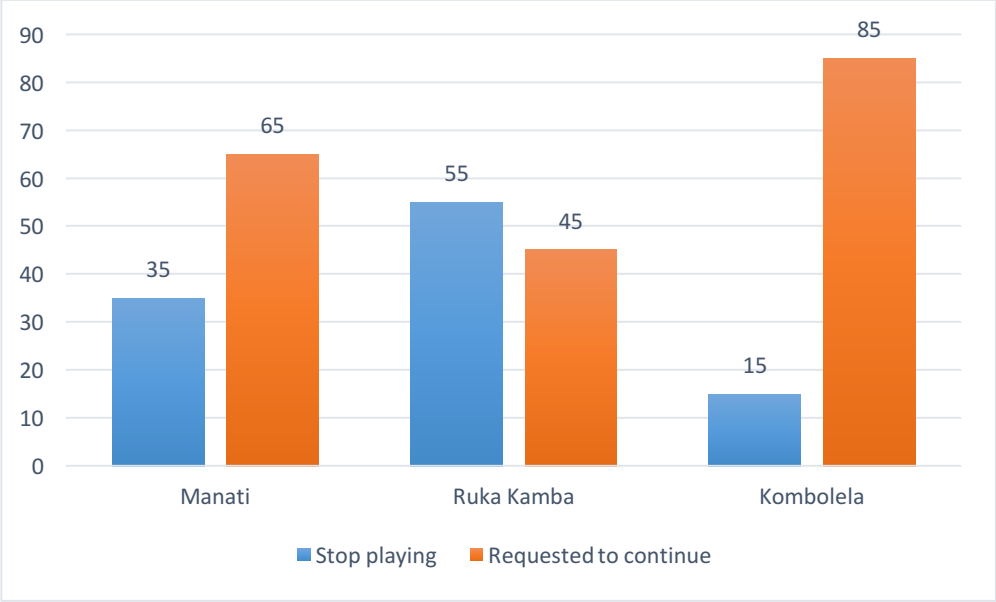

Figure 8: *After 10 minutes of playing session for three games*

Fun and enjoyment

In order to understand how pupils reacted to the games, a team of evaluators reviewed the recorded video and made notes of observations of pupil's behavior as they interacted with the two games: Manati and Kombolela games as sample for this study. The study adopted DEVAN checklist (Vermeeren *et al.*, 2002) used for evaluation of interactive system for note-taking with pupils. The proposed list of breakdown indication types is depicted in Table 1 consisting of eight breakdown indications (Wrong action, Help, Frustration, Bored, Dislike, Impatience, Passive and Perception problem).

Before the actual coding, all evaluators were briefed on the breakdown indication types shown in Table 1 and they were asked to play the games so they could become familiar with them before coding. Evaluators completed their observations individually, before comparing with other members to determine the number of agreements, disagreements and unique observation points. When two evaluators had the same observation point and the same code at this point, it was counted as an agreement. When one of the evaluators had an observation point and the other did not, it was counted as a unique observation for the evaluator that had coded it. When two evaluators had the same observation point but unequal codes this was counted as a disagreement. The results of

each comparison are shown in Table 2, Table 3, Table 4 for Manati, Kombolela, and Ruka Kamba respectively.

Table 1: *Definition of used breakdown indication types*

Code	Short description	Definition
ACT	WRONG ACTION	An action does not belong in the correct sequence of actions. The player clicks objects that are not clickable.
HLP	HELP	The player cannot proceed without help and either asks for it or the researcher has to intervene in order to prevent serious problems.
DSF	FRUSTRATION	That executing the action is difficult or uncomfortable. The effect of an action was unsatisfactory or frustrating.
BOR	BORED	The player verbally indicates being bored. The child non-verbally indicates being bored by sighing or yawning.
DIS	DISLIKE	The player verbally indicates to dislike something.
IMP	IMPATIENCE	The player shows impatience by clicking repeatedly on objects that respond slowly or the user expresses impatience verbally.
PAS	PASSIVE	The player stops playing and does not move the mouse for more than five seconds when action is expected.
PER	PERCEPTION PROBLEM	The player indicates not being able to hear or see something clearly.

Table 2: *Number of agreements, unique observation points and disagreements for Manati game*

Eval A x Eval B	Any-two (%)	Agreements	Unique A	Unique B	Disagreements
Eval 1 x Eval 2	88	79	6	2	3
Eval 1 x Eval 3	90	82	4	3	2
Eval 2 x Eval 3	86	77	3	6	4

Table 3: *Number of agreements, unique observation points and disagreements for Kombolela game*

Eval A x Eval B	Any-two (%)	Agreements	Unique A	Unique B	Disagreements
Eval 1 x Eval 2	85	33	1	5	0
Eval 1 x Eval 3	83	34	0	7	0
Eval 2 x Eval 3	86	36	1	4	1

Table 4: *Number of agreements, unique observation points and disagreements for Ruka Kamba game*

Eval A x Eval B	Any-two (%)	Agreements	Unique A	Unique B	Disagreements
Eval 1 x Eval 2	84	86	7	3	6
Eval 1 x Eval 3	85	85	5	1	9
Eval 2 x Eval 3	93	92	1	4	2

The average of any two agreement for Manati game (i.e. 87.8%) and Kombolela game (i.e. 84.4%), are taken to be perfect agreement. Based on any-two agreement, 53% of all detected problems for Manati game were related to WRONG ACTION (See Figure 9), where a pupil clicks objects/ areas that are not clickable. This happens several times when a player tries to shoot a bird, thereafter they discover the shooting area covers a small part of the screen, rather than their expectation. Most of the time, this problem generated other two problems; that are HELP and FRUSTRATION, where a pupil could not proceed and ask for help or showing the sign of unsatisfactory or frustrating. The Ruka Kamba game had many detected problems compared to Manati and Kombolela, 41% of those problems are related to PASSIVE, where a player stops playing and does not move the mouse for more than five seconds when action is expected. This problem occurred multiple times, when asked by facilitator, a pupil indicates PERCEPTION PROBLEM that he or she has not been able to see jumping clearly.

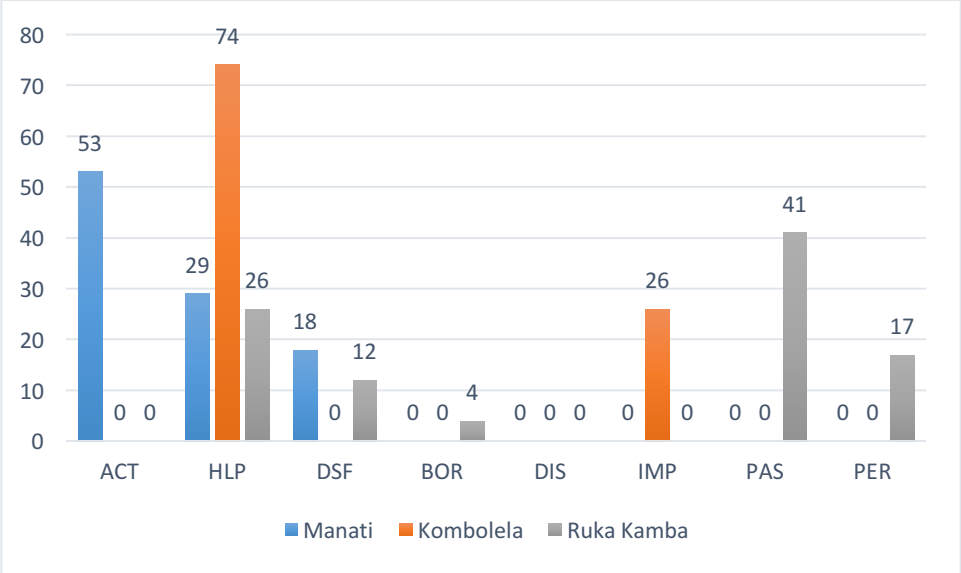

Figure 9: *Percentage of detected problem in developed games*

The Kombolela game had very few detected problems, 74% of those problems are related to HELP, where a child cannot proceed without help and either asks for it or the researcher has to intervene. This problem occurred multiple times when a pupil failed to find a hidden kid, which caused the pupil to express IMPATIENCE verbally or by clicking repeatedly on objects. Generally, evaluators

indicated that the detected problems on both games were very few, indicating that the games were fun and enjoyable amongst pupils who played them. However, Kombolela game was found to be more fun and enjoyable compared to Manati game. The Manati game has to be modified a little bit to cover the detected problems.

Level of difficulty

In addition to direct observations, we were also interested in pupils' opinion in the level of difficult encountered during playing of the games. Mostly, pupils were asked to rank the most difficult game to play amongst the three. The majority of ranked Ruka Kamba (45%) as the most difficulty game to play followed by Manati (35%) and Kombolela (20%).

The most fun and enjoyment game

We also asked children to rate the most interesting game they found and enjoyed playing. Of the 111 pupils who completed the questionnaire, the majority of pupils ranked Kombolela (43%), Manati (36%) and Ruka Kamba (21%) in order as the most fun and enjoyable games.

Teachers' opinions on pedagogical usefulness of the games

During focus group interview, teachers were asked to provide their opinion on the usefulness of the developed games for enhancing numeracy skills. The findings indicate the many teachers agreed that the developed games are useful and can enable those children who will play regularly improve numeracy skills. First, teachers were asked their opinion on the content and skills presented in the developed games if they are pedagogical effective. It was interested that many teachers indicated that the developed games can have the potential to improve numeracy skills. Some of the comments are:

> *"These games will give children the chance to learn own their own at their own pace. The Manati game for instance, can make a positive difference in how children learn number identification" (Teachers 4 in Group 3).*

> *"The strength of these games lies on the ability of pupils to play on their own without the presence of teachers or parents. They are simple to play and I don't think many children will struggle to play. Number counting in Ruka Kamba to me is well covered and I am sure for those who will be playing regularly, are likely going to learn counting skills" (Teachers 1 in Group 1).*

However, teachers provided their comments for further improvements of the games. One important comment suggested by many teachers was the availability of the games in both languages i.e. Swahili and English. The current games have been developed and made available in Swahili. It was noted by many teachers that there many English media private schools in Tanzania where they would also love to use these games. Therefore, developers should plan to have two versions of the games if they need to target these schools. Some of teachers' comments are:

> *"The game should contain both languages (i.e. Swahili and English) in order to assist other children in English medium schools. Almost one third of the schools located in cities like Dar es Salaam are English medium and are the one who could use these games" (Teacher 3 in Group 2).*

> *"Are you planning to commercialise these games? The potential market is in schools located in towns and the majority are English medium schools. Unfortunately, they use*

> *English and will find these games useful if they are made in English too. So, think about it" (Teacher 1 in Group 1).*

On the content of the games, some teachers indicated that the games have very elementary skills and they suggested to increase levels from 5 to at least 15 levels. For example, one teacher suggested

> *"The games are so elementary, I would suggest you increase the number of levels, let say up to level 10 or 15 especially on the Ruka Kamba so that pupils can learn to count up to 15 or even more" (Teacher 4 in Group 1).*

Some teachers were skeptical on the availability of these games in tablets and mobile phones indicating that these devices are not accessible to the majority of pupils in Tanzania. They are not only expensive to the majority of parents but also difficult to manage as pupils will keep on dropping them. For instance, one teacher said:

> *Playing games via tablets is real beautiful and children do enjoy it. But I am worried about those children in rural areas where the majority of their parents cannot afford them. It is not possible for some parents to spend Tsh 300,000 (US$ 150) for tablets with games. I am sure they cannot (Teacher 3 from Group 2).*
>
> *Children under the age of 6 love playing, and with these delicate gadgets I m sure they will not stay long. We will keep on fixing them every day as they will be dropping them and damaging them. I would recommend the use of laptops or computers than tablets or mobile phones (Teacher 2 from Group 2).*

When asked their suggestions on which media or devices they think the games should be distributed to pupils. The majority of teachers indicated that for teaching purposes, the games should be installed in computers for schools with computer labs. Moreover, some teachers suggested that the games should be available via DVDs or CD to enable some parents who are interested so that they can buy.

> *"It is easier to use them and manage them if they are installed in our computer labs here at the school. So, pupils will be given time to go there and play. They should not be playing games all the time but we can locate enough time let us say one hour per day for them to play these games (Teacher 1 from Group 3)."*
>
> *"In schools with few computers, these games burned into DVD or CDs and give them to parents so that they can play at home. Some parents have computers so it will be easier for them to install into their computers. I don't know your plan but I am sure many parents will be happy to buy once we recommend to them" (Teacher 3 from Group 3).*

Finally, teachers were asked if these games can be used to complement face to face classroom teaching. Many teachers indicated that they can provide a useful complement in schools with large number of pupils. Some of the comments are:

> *"Currently, there are several teaching challenges, such as lack of teaching resources and lack of qualified pre-school teachers, hence efforts of games like these can be used to complement these existing teaching challenges in pre-schools"* (Teacher 2 from Group 1).

> *"Teaching a large class poses many challenges, including lack of teacher-child interactions which support kids' development on certain areas, the such games provide high level of child engagement on numeracy with minimum supervision"* (Teacher 3 from Group 2).

DISCUSSION

This study was set to redesign and digitize local games that children used to play into digital games so that they can be used to stimulate interest of pupils in learning numeracy skills in Tanzania. Proponents of play as enhancing children's learning have much evidence to cite (Colliver, 2017) and many digital games have been developed and used to improve learning outcome in many levels of education in developed world (Ferreira, Gouin-Vallerand and Hotte, 2016). However, there have been few efforts to develop digital games that can be used to stimulate interest of pupils in learning outcome in the context of developing countries.

As the ICT infrastructure in developing countries grows especially mobile penetration and the Internet, then so will the use of digital games grows. The price of computers as well as mobile devices has been decreasing to as low as US$ 30 in many developing countries (Deloite and GSMA, 2012; Ericsson, 2014). The continued penetration of mobile telephony in Africa has been Leapfrogging the Digital Divide that has been existing for a long time (Adkins, 2013). As result, many firms have continued to develop games and share them via mobile phone and the Internet. At the moment, the majority of existing digital games have been developed in the context of western culture in which many children in developing countries have little exposure to them. These games do not match the understandings that rural children have about games and therefore they do not find them enjoyable or free from playability problems (Kam *et al.*, 2009; Nolan and McBride, 2013). From the social constructivism perspective, children learn from interactions with other people and with the environment in which they live (Su and Cheng, 2015; Subrahmanyam and Renukarya, 2015). Therefore, when educational games are developed for certain social and cultural context they cannot be used appropriately to improve children learning in a different context.

This study was set to redesign local games that children used to play in their daily lives into digital games that can be played via mobile devices and computers. Three games namely Manati, Ruka Kamba, and Kombolea were designed and developed. The developed games were piloted at Mlimani primary school with 111 students, 12 teachers using questionnaire, direct observation, and focus group interviews.

Studies have shown designing games that are enjoyable and educationally effective is challenging as it involves an effective balance between learning theories and game elements making the game fun and enjoyable (Khanana and Law, 2013; Iten and Petko, 2016). Poorly designed games can be time-wasting while contributing little in children's learning activities (Lieberman, 2006; Christakis and Zimmerman, 2009). Therefore, we followed principles and game elements of the game design proposed by Plass et al. (2015) in order to develop games that will be educational effective but at the same time are enjoyable to play.

The study found that teachers indicated that the developed games were pedagogical effectiveness and that they have the content and skills necessary to be applied in the classroom to enhance numeracy skills especially for counting and numeracy skills. However, the majority of teachers were skeptical on the use of tablets and mobile phones since these devices are not affordable to the majority of parents. Moreover, these devices can easily be damaged if they are used to complement classroom environment given a number of pupils in Tanzania classrooms. The use of computers and laptops were proposed. This finding was contrary to the fact that the vast majority of preschool

game based learning have been made available via mobile phones (Adkins, 2013) and that many pupils in developing countries tend to play via their parents' mobile devices.

This study managed to test the usability and playability of the developed games. The majority of pupils found the developed games were easily to play, enjoyable, fun and imitated local games they used to play in schools and at home. With exception of Ruka Kamba which was found to be slightly difficult to play but the other two games were found to enjoyable. This was evident from the fact that more than 50% of pupils who were observed playing the games indicated that they wanted to play even beyond playing session. These findings further confirm that the use of XP practices in developing these games managed to capture all necessary reequipments. Moreover, games design elements for learning proposed by Plass et al. (2015) were effective in developing games that were enjoyable but also pedagogical effective. However, developers were asked to use the findings of this study to improve the usability and playability of the Ruka Kamba game.

Surprisingly, the study found that Kombolela was the most enjoyable and easy game to play through both direct observation and data from questionnaire. This finding could be explained by the fact that this is a common game that is usually played by pupils of both sex and therefore it was likely that they are both going to enjoy. On the other hand, Ruka Kamba was found to be less interesting amongst pupils and that was found to be difficult to play as compared to other games. A possible explanation of this finding is that the majority of pupils participated in the study were boys and the Ruka Kamba game is normally played by girls. Possibly, boys did not have interest in Ruka Kamba game as they normally do not play in their day to day games.

RECOMMENDATIONS FOR FUTURE RESEARCH

In light of the above limitations, there are several recommendations for future research studies. It should be noted that the interactive games were tested a small population of pupils and teachers in a public school from Dar es Salaam where availability of smartphones and usage is high. Further work is required to establish the practicability of the digital games using a large population size representing various geographical regions. Another crucial limitation of this study which could be addressed in future studies is the scope of the study where pre-test and post-test can be conducted to examine the effect of digital games in enhancing numeracy skills. Moreover, the span of the study was only six months. This was a short amount of time, a longer period of study might offer more data and reflect different patterns or trends in digital games usefulness, usability, and playability. Despite these few limitations, the study has managed to demonstrate how local games can be redesigned and be played in mobile devices to contribute improving numeracy skills in developing countries.

CONCLUSION

The value of learning through playing digital games has been recognized in the children's education field for more than a decade. However, many parents and educators especially in developing countries still tend to think digital games are harmful or wastage of time to children. It is true that if children play violent games, they are likely to learn and accept violence as a legitimate way to solve problems (Gros, 2007). However, games designed to teach more valuable lessons such as numeracy skills can also be effective, and the curriculum of games has been expanding into new topic areas every day (Lieberman, 2006). If this is not enough, children who frequently play educational games perform better than those who do not (Lieberman, 2006).

Given the continued improvement of ICT infrastructure as well as the penetration of mobile phone in Africa, the use of games for learning cannot be ignored. In fact, tens of millions of people in

developing countries play entertainment computer games on a regular basis (Heeks, 2008). One major problem is that due to lack of local games that have been developed for children in developing countries. This study has demonstrated that local games can be redesigned into digital form and therefore be used to improve numeracy skills in developing countries.

REFERENCES

Adkins, S. S. (2013) *The 2012-2017 Worldwide Game-based Learning and Simulation-based Markets*. Available at: http://www.ambientinsight.com/Resources/Documents/AmbientInsight_SeriousPlay2013_WW_GameBasedLearning_Market.pdf.

Alfadhli, S. and Alsumait, A. (2015) 'Game-Based Learning Guidelines ':, *IEEE Conference Publications*, (2014).

Anderson, K. and Sayre, R. (2016) *Measuring Early Learning Quality and Outcomes in Tanzania Institutional assessment for integrating early childhood measurement in the pre-primary system*. Available at: https://www.brookings.edu/wp-content/uploads/2017/06/melqo-measuring-early-learning-quality-outcomes-in-tanzania_2016oct.pdf.

Andersson, U. and Lyxell, B. (2007) 'The contribution of working memory to children's mathematical word problem solving', *Journal of Experimental Child Psychology*, 21(9), pp. 1201–1216. doi: 10.1002/acp.1317.

Ardito, C. *et al.* (2005) 'An approach to usability evaluation of e-learning applications', *Universal Access in the Information Society*, 4(3), pp. 270–283. doi: 10.1007/s10209-005-0008-6.

Author Name (2018) 'Using eXtreme programming practices in developing digital games for improving numeracy skills in Tanzania', *The Electronic Journal of Information Systems in Developing Countries*, Acccepted.

BEST (2013) *Basic education statistics in Tanzania (BEST)*. Dar es Salaam :Tanzania. Available at: https://searchworks.stanford.edu/view/6648018.

BEST (2016) *Basic education statistics in Tanzania (BEST)*. Dar es Salaam, Tanzania. Available at: https://searchworks.stanford.edu/view/6648018.

Bottino, R. M. *et al.* (2007) 'Developing strategic and reasoning abilities with computer games at primary school level', *Computers and Education*, 49(4), pp. 1272–1286. doi: 10.1016/j.compedu.2006.02.003.

Christakis, D. a and Zimmerman, F. J. (2009) 'Young Children and Media: Limitations of Current Knowledge and Future Directions for Research', *American Behavioral Scientist*, 52(8), pp. 1177–1185. doi: 10.1177/0002764209331540.

Colliver, Y. (2017) 'Fostering young children's interest in numeracy through demonstration of its value: the Footsteps Study', in *Mathematics Education Research Journal*. Mathematics Education Research Journal. doi: 10.1007/s13394-017-0216-4.

Connolly, T. M. *et al.* (2012) 'A systematic literature review of empirical evidence on computer games and serious games', *Computers and Education*. Elsevier Ltd, 59(2), pp. 661–686. doi: 10.1016/j.compedu.2012.03.004.

Deloite and GSMA (2012) *Sub-Saharan Africa Mobile Observatory 2012*. Available at: http://www.gsma.com/spectrum/sub-saharan-africa-mobile-observatory-2012/.

Donlan, C. *et al.* (2007) 'The role of language in mathematical development: Evidence from children with specific language impairments', *Cognition*, 103(1), pp. 23–33. doi: 10.1016/j.cognition.2006.02.007.

Ericsson (2014) *Sub-Saharan Africa Ericsson mobility report*. Stockholm, Sweden. Available at: http://www.ericsson.com/res/docs/2014/emr-june2014-regional-appendices-ssa.pdf.

Ferreira, S. M., Gouin-Vallerand, C. and Hotte, R. (2016) 'Game based learning: a case study on designing an educational game for children in developing countries', in *8th International Conference on Virtual Worlds and Games for Serious Applications*, p. 8.

Glang, A. *et al.* (2005) 'Using interactive multimedia to teach pedestrian safety: An exploratory study', *American Journal of Health Behavior*, 29(5), pp. 435–442. doi: 10.5555/ajhb.2005.29.5.435.

Godoy, A. and Barbosa, E. F. (2010) 'Game-Scrum: An Approach to Agile Game Development', in *SBC - Proceedings of SBGames*, pp. 292–295. Available at: http://www.sbgames.org/papers/sbgames10/computing/short/Computing_short19.pdf.

Griffiths, M. and Davies, M. N. O. (2002) 'Excessive online computer gaming: implications for education', *Journal of Computer Assisted Learning*, 18(3), pp. 379–380.

Gros, B. (2007) 'Digital Games in Education : The Design of Games-Based Learning Environments', *Journal of Research on Technology in Education*, 40(1), pp. 23–38.

Heeks, R. (2008) 'Computer Games and Developing Countries: A Research Agenda', *Learning*, (8), pp. 1–5. Available at: http://hummedia.manchester.ac.uk/institutes/gdi/publications/workingpapers/di/di_sp08.pdf.

Iten, N. and Petko, D. (2016) 'Learning with serious games: Is fun playing the game a predictor of learning success?', *British Journal of Educational Technology*, 47(1), pp. 151–163. doi: 10.1111/bjet.12226.

Kam, M. *et al.* (2009) 'Designing Digital Games for Rural Children: A Study of Traditional Village Games in India', in *Human-Computer Interaction*. Boston, Massachusetts: ACM New York, NY, USA, pp. 31–40. doi: 10.1145/1518701.1518707.

Khanana, K. and Law, E. L.-C. (2013) 'Designing children's digital games on nutrition with playability heuristics', in *CHI '13 Extended Abstracts on Human Factors in Computing Systems on - CHI EA '13*, p. 1071. doi: 10.1145/2468356.2468548.

Kirriemuir, J. and McFarlane, A. (2004) *Literature Review in Games and Learning*, *A NESTA Futurelab Research report - report 8. 2004.* Available at: https://telearn.archives-ouvertes.fr/hal-00190453/file/kirriemuir-j-2004-r8.pdf.

Kisakali, J. and Kuznetsov, D. (2015) 'Modeling Factors Influencing Mathematics Learning and', *Asian Journal of Mathematics and Applications*, pp. 1–11.

Lieberman, D. a., Fisk, M. C. and Biely, E. (2009) 'Digital Games for Young Children Ages Three to Six: From Research to Design', *Computers in the Schools*, 26(4), pp. 299–313. doi: 10.1080/07380560903360178.

Lieberman, D. a (2006) 'What can we learn from playing interactive games?', in *Playing video games: Motives, responses, and consequences*, pp. 379–397. doi: 10.4324/9780203873700.

McLean, J. F. and Hitch, G. J. (1999) 'Working memory impairments in children with specific arithmetic learning difficulties', *Journal of experimental child psychology*, 74(3), pp. 240–260. doi: 10.1006/jecp.1999.2516.

MoEVT (2012) *Report and Analysis of the Results*. Dar es Salaam, Tanzania.

Nolan, J. and McBride, M. (2013) 'Beyond gamification: reconceptualizing game-based learning in early childhood environments', *Information, Communication & Society*, 4462(June 2013), pp. 1–15. doi: 10.1080/1369118X.2013.808365.

Ogletree, S. M. and Drake, R. (2007) 'College students' video game participation and perceptions: Gender differences and implications', *Sex Roles*, 56(7–8), pp. 537–542. doi: 10.1007/s11199-007-9193-5.

Petrillo, F. *et al.* (2008) 'Houston, we have a problem...: A Survey of Actual Problems in Computer Games Development', in *Proceedings of the 2008 ACM symposium on Applied computing - SAC '08*, pp. 707–711. doi: 10.1145/1363686.1363854.

Plass, J. L., Homer, B. D. and Kinzer, C. K. (2015) 'Foundations of game-based learning', *Educational Psychologist*, 50(4), pp. 258–283. doi: http://dx.doi.org/10.1080/00461520.2015.1122533.

Praet, M. and Desoete, A. (2014) 'Enhancing young children's arithmetic skills through non-intensive, computerised kindergarten interventions: A randomised controlled study', *Teaching and Teacher Education*. Elsevier Ltd, 39, pp. 56–65. doi: 10.1016/j.tate.2013.12.003.

Prensky, M. (2001) 'The Digital Game-Based Learning Revolution', in *Digital Game-Based Learning*, pp. 1–19. doi: 10.1016/j.iheduc.2004.12.001.

Su, C. H. and Cheng, C. H. (2015) 'A mobile gamification learning system for improving the learning motivation and achievements', *Journal of Computer Assisted Learning*, 31(3), pp. 268–286. doi: 10.1111/jcal.12088.

Subrahmanyam, K. . b and Renukarya, B. . (2015) 'Digital Games and Learning: Identifying Pathways of Influence', *Educational Psychologist*, 50(4), pp. 335–348. doi: 10.1080/00461520.2015.1122532.

Sumra, S. and Katabaro, J. (2016) *Education Foundations of the Development of Skills and Productive Capabilites*. Available at: http://www.thdr.or.tz/docs/THDR2017BP-10.pdf%5Cnhttp://esrf.or.tz/docs/THDR2017BP-10.pdf.

UNESCO (2015) *Education for All 2000-2015: Achievements and Challenges - EFA Global Monitoring Report 2015*. Paris, France. Available at: http://en.unesco.org/gem-report/report/2015/education-all-2000-2015-achievements-and-

challenges#sthash.ap6wdoXI.dpbs.

UWEZO (2011) *Are Our Children Learning? Annual Learning Assessment Report*.

Vermeeren, A. P. O. S. *et al.* (2002) 'DEVAN: a detailed video analysis of user test data', *Behaviour & Information Technology*, 21(6), pp. 403–423. doi: 10.1080/0144929021000051714.

Wang, C.-S., Liu, C.-C. and Li, Y.-C. (2011) 'A game-based learning content design framework for the elementary school children education', in *The 16th North-East Asia Symposium on Nano, Information Technology and Reliability*, pp. 53–57. doi: 10.1109/NASNIT.2011.6111121.