See Me Roar: an AR Game to Improve Children's Perception of Relatedness and Learning Motivation in Elementary Math Education

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ABSTRACT
Today's primary school teachers may find it hard to motivate their students into traditional learning activities, especially with subjects which students may find difficult and are subsequently not willing to spend much time on, such as mathematics. Educational games with Augmented Reality (AR) technology could provide a great potential for learning and are increasingly available among primary school students. However, there is a lack of understanding on how to improve student's learning motivation through the AR educational games. In the present study, the researcher first used the method of co-design with children to shape and develop the concept of an AR game for children to practice their math skills in the social learning environment. Then, the researcher conducted a user test with four 8-12-year-old students to explore which game elements (collaboration vs. competition) in the AR game could improve their perception of relatedness and motivation based on Self-determination Theory. The results show that the collaboration version could lead to a higher perception of relatedness and more learning motivation.

Author Keywords
Augmented Reality; Children; Motivation; Relatedness; Game Design; Participatory Design

INTRODUCTION

It has been suggested that mathematics is relatively more challenging compared with other primary school subjects, thus causing mathematics learning difficulties in primary grades [1, 2, 3]. Meanwhile, learning motivation and interest have been proven to be an important factor in affecting children's learning performance [3]. Consequently, how to motivate primary school students to get involved in the learning activities has been a concern for many mathematics teachers.

To engage children in a wide range of learning activities, Hakan Tüzün proposed that students demonstrate a higher intrinsic motivation in the game-based learning environment [4]. Frequently-cited arguments for the benefits of using games in education include invoking intense engagement, encouraging active learning by doing, enhancing a deeper understanding of complex subjects, and fostering collaboration among learners [5]. Accordingly, it can be seen that educational games are qualified to serve as a learning tool in classrooms, and these serious games are widespread among young students [6]. However, many educational games are computer-based, ignoring the advantages of face-to-face social interaction.

Equipped with AR technology, educational games can show some advantages over normal ones in some respects. Above all, AR applications can immerse children in the learning contents by displaying 3D virtual animations in the real environment [7, 8]. Besides, AR technology encourages social interaction among students by presenting similar or different contents, thus allowing them to connect with each other or work on a mutual task [9, 10].

To explore why social interaction is related to learning motivation, the researcher turns to Self-determination theory (SDT), which explains why people are motivated to engage and put an effort in an activity [11]. Among the three psychological needs of SDT, "relatedness" can explain the effect of social interaction, which means a feeling of social connectedness with each other [11]. In this research project, the researcher developed the game based upon the first version of See Me Roar [12]. This paper describes how the researcher expanded the game with social factors (collaboration and competition) and explored how could these social factors encourage children to feel connected and motivated in math learning.

The researcher first reviewed current studies and AR educational games related to learning motivation and social interaction. Then the researcher conducted a participatory design with children to identify design features to be applied in the game. After confirming the game concept and developing a working prototype in Unity 3D, a user test was carried out with children. By analyzing the data from this experimental study, the researcher could investigate to what extent children feel related with each other and the way children could be motivated in game experience with different social elements.

RELATED WORK

Motivation in AR Learning Games

Numerous AR-based educational games have emerged to pose a positive effect on motivating children in learning activities [13].

Innovative and immersive technologies like Augmented Reality in the classroom do improve students' learning motivation [14]. Chen & Tsai [15] have designed an educational AR system to provide library instructions for elementary students, and it has demonstrated that applying AR technology significantly contributes to their learning performance. A math learning game for kids, which is called "Math Ninja AR" [16], overlays a Japanese-inspired town in the real environment by using AR technology, in order to create a magical world for young kids and motivate them to practice math.

In addition to the feature of AR technology, physical objects in AR games could also be a powerful supplement to get students involved. Educational Magic Toys (EMT) [17] were developed by Rabia M. Yilmaz with AR technology to teach 5-6 age children with animals, fruits, vegetables, vehicles, colors, numbers and shapes. EMT consists of an application and a physical toolkit including puzzles and cards, on which different patterns are printed. This physical toolkit has great importance because it provides self-motivation for children and shape their learning experience [17].

Even though children would show a higher motivation towards AR games compared with non-AR games [18], there are still concerns that the novelty effect fading away may lead to children's losing interests towards the game [19, 20]. Besides, according to Wouters, few of these games have integrated with the school syllabus such as the learning contents in textbooks [21], thus leading to the irrelevance of AR games and what students should learn in elementary education.

Therefore, it is necessary to gain a deeper understanding of the motivational factors in AR serious games, and to integrate AR learning games with ordinary teaching materials so that children will not lose their learning goals.

Social Interaction in AR learning games

Considering the importance of social interaction in *classroom goal structure*, which describes three ways of students interacting with each other and their teachers: cooperative, competitive, and individualistic [22, 23], the researcher tends to hypothesize social interaction as an essential feature in student motivation. Social interaction in learning could give children opportunities to establish relationships, share opinions, and feel a sense of involvement [24, 25]. Children could benefit from interacting with their peers who are friendly, approachable, and positive, because of the perception of belonging and relatedness [26].

There are many AR-based learning games supporting social interactions among players. Karen Schrier has designed an AR game "Reliving the Revolution" (RtR) [27], which could teach 21st-century skills such as communication skills in different ways, including the physical environment and collaborative-intensive gameplay. The application "AR PRISM" [28] visualizes geographic data, and supports face-to-face collaboration and object-based interaction with the real environment. Participants gathering around a real map are able to see 3D virtual contents and each other through a headset, thus contributing to the social interaction among multiple users. Another vocabulary AR game uses a spelling test, requiring students to compete to learn all the situated English which are spread around the AR surroundings [29].

Self-Determination Theory

Self-Determination Theory (SDT) is chosen as the theoretical framework to design the See Me Roar, since it is expressive in the fields of education and games [11, 30]. Within SDT, when the needs for competence, autonomy, and relatedness are satisfied, people would tend to internalize the surrounding values and regulation [11, 31, 32]. In other words, these three psychological needs facilitate the internalization and integration of extrinsic motivation [11]. After internalization, the intrinsic motivation poses a reason for doing something, which is because of the inherent interest and enjoy [33].

The researcher believes the SDT framework could lead to practical guidance for a well-designed educational game. Among these three components, the need for "relatedness" which means the feeling of social connectedness with each other [34], is closer to the social aspect of AR learning games. In social games, relatedness is associated with a student's feeling that the partners genuinely like, respects, and values him or her [35]. Therefore, serious games should make full use of the communication advantages within the classroom, such as collaborating, competing, negotiating, plotting, etc. [30].

RESEARCH QUESTION

The researcher has formed the research question and two hypotheses. By answering the research question, the researcher seeks to explore how to design AR educational games for children in a better way to provide a sense of relatedness and engagement.

RQ: What kinds of game elements in See me Roar could improve children's perception of relatedness and their learning motivation?

H1: Collaboration could trigger the perception of relatedness among primary school students and improve their learning motivation.

H2: Competition could trigger the perception of relatedness among primary school students and improve their learning motivation.

PARTICIPATORY DESIGN WITH CHILDREN

In this section, the researcher has applied the participatory design (PD) method, aiming to explore more design features and possibilities by involving the target students in the early design phase. The overall process involved:

1. Identifying the methods and techniques
2. Setting up for the PD
3. Recruiting the participants
4. Conducting the PD
5. Analyzing the data

Methods

As for the methods for PD, the choice of Cooperative Inquiry (CI) was due to its important feature in equally valuing the opinions of both children and adults [36]. ‘‘Cooperative inquiry offers a set of techniques that can be used by teams of adults and children together throughout the design process’’ [37]. Unlike the informant design, where children are only consulted and adults are in charge, in the CI method, children and adults need to work throughout the entire design process, by applying a range of techniques [36, 38].

To elicit design ideas directly, the technique of low-tech prototyping was introduced for the early stage of the design. With a bag of low-tech art supplies and toolkits, design teams could build a low-tech prototype. Research has also proved that children came up with more ideas as a result of a low-tech prototyping activity [39].

Evaluation is an essential part of an iterative design process [40], so in the second phase, design teams used the sticky notes technique to evaluate prototypes and provide feedbacks to each other.

In the iteration phase, participants also needed to use the low-tech prototyping technique to adapt their design to support the collaboration of primary school students.

Environment and Materials

Two rounds of PD were held in two meeting rooms (Figure 1 *left*) separately in the Atlas Building on campus. The equipment in the meeting room contained a round table with several chairs around, a whiteboard and a TV screen.

Based on the instructions from JA Fails [36], the researcher has prepared some prototyping toolkits (Figure 1 *right*) to be used in the PD. This is the list of toolkits:

- Animal stickers with over 30 kinds of animals
  - Serving as the main elements for the game, animals were chosen as the main role in their scenario, which they created in the paper prototype.
- Ordinary tools
  - Glue, scissors, tape, eraser, pencil
  - A3 white paper
  - Colored pencils and markers
  - Colored paper
  - Colored sticky notes
- 3D components
  - Colored clay
  - Blue and red sponge
  - Two-color tubes
  - Yarn

In addition to the materials for prototyping and evaluation, voice-recorder and consent form were also prepared for the participatory design.

Figure 1. The environment of the meeting room (left) and prepared toolkits for prototyping (right)

Participants

The participants consisted of three primary school students at the age of 8-12, one 18-year-old male as co-designers, as well as three college students as facilitators. The role of the adult participants was facilitating a collaborative experience with children participants and helping them elaborate ideas in a better way. The college students also helped translate the presentation and conversation during the session.

Due to the time coordination problems, the PD was divided into two lots on two different dates. Table 1 shows the information of all co-designers and facilitators in each round.

Participants	Age	Gender	Round
P1 (co-designer)	12	female	1
P2 (co-designer)	18	male	1
P3 (facilitator)	27	female	1
P4 (co-designer)	10	female	2
P5 (co-designer)	11	female	2
P6 (facilitator)	22	female	2
P7 (facilitator)	27	female	2

Table 1. Co-designers and facilitators in PD

In the first round, one child (P1) was chosen based on the fact that she could understand the math contents in primary school. Besides, two adults were also invited in this co-design process, one of whom is her brother (P2), and the other one is a university student (P3).

In the second round, the children participants (P4, P5) are two female children at the age of 10-11 years old. The two adult participants (P6, P7) are university students with a design background. All the participants were divided into two groups with one child and one adult in each group.

Procedure

The procedures of the two rounds co-design were the same, and the whole session was recorded:

- Step 1: the researcher proposed the design challenge, research background, duration, and format to all the participants. Their parents also needed to sign the consent form in this step, allowing the researcher to record the conversations and take photos of the children.
- Step 2: each team needed to come up with a scenario through low-tech prototyping to make the math exercise more fun for primary school students (Figure 2 *top*). After prototyping their concept, they need to give a short presentation about their design concepts.
- Step 3: participants were asked to write down “like” and “don’t like” on sticky notes towards the other team’s design concept. Each idea was written on an individual sticky note and placed on a whiteboard.
- Step 4: design teams were required to use the toolkits to iterate their design ideas into a multi-player version. After that, they also needed to present their adapted ideas.

Figure 2.a, 2.b shows the scenario of low-tech prototyping

Figure 2. The scenario of low-tech prototyping (a) (b), as well as their generated prototypes and evaluations (c) (d)

Data Analysis

Thematic analysis is one of the most common methods of analysis in qualitative studies. According to the analysis process recommended by Lazar et al. [41], the researcher followed three techniques to analyze the results.

Firstly, the researcher defined a group of items and themes for coding (Table 2). Second was drilling down into each item to find relevant descriptive properties and dimensions. The last technique was making comparisons of data sources, including the generated prototypes (Figure 2.c, 2.d), the contents on sticky notes, and children’s verbal presentations. After finishing all these techniques, the data sources can be categorized into the coding items (Figure 3).

Item	Definition
Math Content	The knowledge point of math appearing in the game
Interaction	The form of interaction among students
Gam Feature	The mechanism and game elements showed in the game

Table 2. Defining a set of coding items

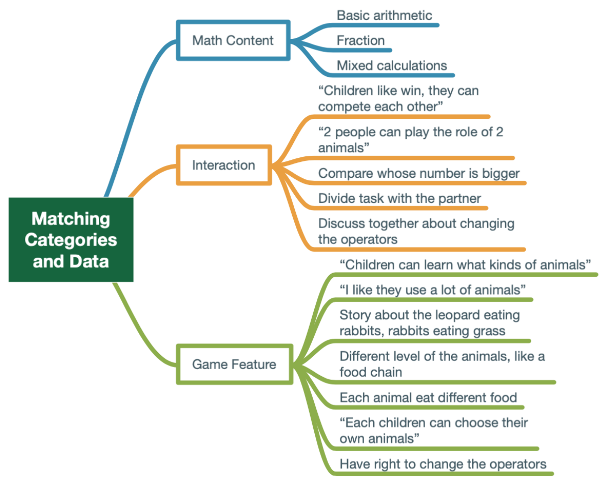

Figure 3. Data set categorized into the coding items

Findings

After organizing the data into categories, the researcher was able to identify patterns and connections within or between the categories.

Design features in the game

For forming the game concept, the topic of animals was highly appreciated due to many reasons, for instance, children could learn some common sense of animals. Besides, nearly all participants have mentioned about using avatars to represent themselves. They highly praised the choice of various animals and playing their roles in the game. The concepts of animals eating food and food chain have also been reflected in some prototypes.

How do children interact with each other in the game?

When asking children participants to adapt the game for multi-players, one child designed an idea of competing for the animal’s speed of eating food. Some children have presented that task division can also enhance collaboration. Therefore, competition and collaboration were two major aspects being embodied in their prototypes.

Reflection of the PD process

In the low-tech prototyping phase, participants were not willing to use 3D components, possibly because of the difficulties of building a three-dimensional model. It is recommended that without special needs, such as building a tangible 3D prototype, 3D components are not necessary for making low-tech prototypes.

In addition, the researcher found that participants were not willing to provide negative opinions to other prototypes in the evaluation phase. Hence, the period of posting “like” and “dislike” should be separated and given more time so that they can go deeper into assessing other prototypes.

CONCEPT AND IMPLEMENTATION OF THE GAME

Inspired by the insights from the co-design with children, the researcher has validated using animals as the main topic, and the animals eating food was chosen as the main mechanism to provide children a motivating learning environment in doing their math exercises.

Two Versions of the Game

Based on the key elements, competition and collaboration, which were acquired from the PD and literature review (mentioned in related work), the researcher has designed 2 versions for this game.

In the beginning, children need to be divided into groups (e.g. 2 students per group). Then each child can choose an animal avatar to represent themselves during the game (Figure 4 *top*). Children scan the map of the newly-designed textbook sequentially and finish the math exercises on the screen. Except for the math exercise, the food containing different answers are also spread on the page, with only one answer is correct. Children need to control the animals to move towards the food with the correct answer.

Competitive version

In this version, the group members compete with each other about who can move the animals to the "correct" food at a higher speed (Figure 4 *bottom*). The child who gets the "correct" food faster will win the game, and the other child will receive an alert informing the correct answer. One thing to be mentioned is that if the food with a wrong answer is touched, there will be a cute animation such as crashing down the food, instead of an alert notifying the mistake, in order to avoid feeling frustrated.

Collaboration version

In this version, the tasks of the group members are different, with one child can only see the exercises, the other one can only control the animals. Consequently, being not allowed to gaze at the partner's phone, they have to collaborate with each other to eat the "correct" food.

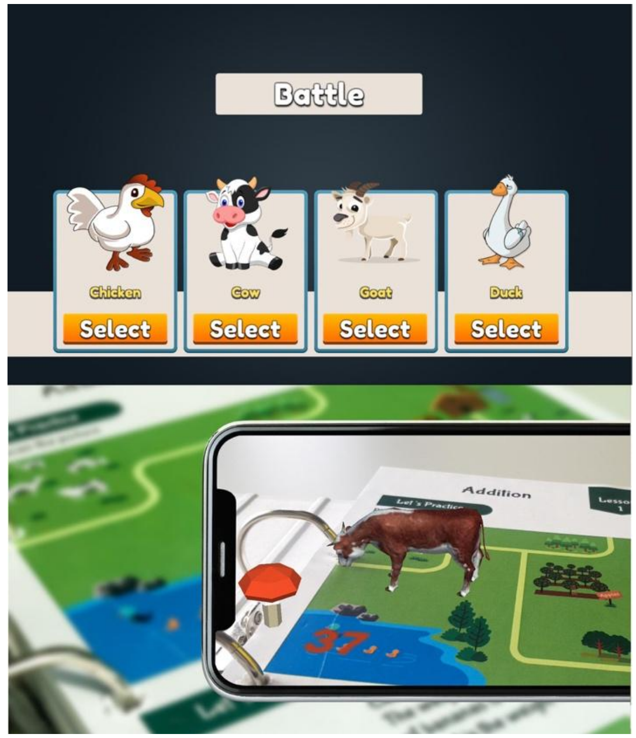

Figure 4. AR game design

Design and Implementation of the Prototype

The prototype of the game consists of a tangible textbook and an Android AR application.

Designing the tangible textbook

The textbook contains a series of math subjects including addition, subtraction, multiplication, and division. In each subject, there is a map to be scanned for math exercise, worksheet for homework, and knowledge point explanation. Figure 5 shows two pages of the textbook as an example.

In terms of the visual style, the researcher chose a suitable font, colors, and illustrations to make it more friendly and fun for children. Firstly, the font Bubblegum Sans is highly readable and subtle, but still offers a greater degree of whimsy than the usual fonts. Secondly, a collection of high brightness and contract colors are used to attract children’s attention. Thirdly, many cartoon illustrations are designed in the textbook to explain knowledge instead of long texts, so that children can master the whole concept and knowledge quickly and easily.

Maps are designed as continents where animals can run and eat food. Through AR technology, 3D environment and elements including animals, food, and other decorations appear above the map to enhance the realistic sensation. Every topic of a map represents a math subject, with its correspondent animals and environmental elements (Table 3). The goal of designing various maps is to provide children with a sense of exploration and adventure when they learn new knowledge.

Math subject	Map	Animals
Addition	Farm	chicken, cow, goat, duck
Subtraction	Sea	shark, seagull, dolphin, whales
Multiplication	Desert	camel, eagle, rabbit, zebra
Division	Forest	deer, elephant, giraffe, fox

Table 3. List of the correspondent map and animals to each math subject

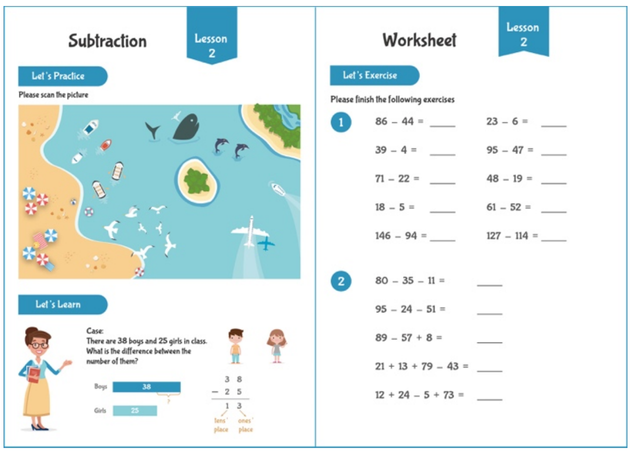

Figure 5. Textbook design

Implementation of the AR application

Serving as the basic technology, Computer Vision (CV) is applied in the development of AR applications, which means 2D images in the user's environment are predefined to trigger the display of AR overlays on the screen. In this game, the predefined images are the maps printed on the textbook.

The mobile application is developed in Unity 3D, which is a cross-platform game engine with a built-in IDE. The Vuforia software development kit (SDK) is also used to provide API in programming languages and recognize the image targets.

USER TEST

After formulating the design concept and prototyping it, the researcher conducted a user test on children with the working prototype. The goal of the user test was to understand how children collaborate and compete with each other and how they perceive relatedness in the two versions of the game.

The overall process involved:

1. Identifying the methods
2. Setting up for the user test
3. Recruiting children participants
4. Conducting the user test
5. Analyzing the qualitative data

Methods

Due to the limited number of children participants for the user test, semi-structured interview and observation were chosen to explore deeper from the participants and collect qualitative data.

Observation

Considering the difficulties of eliciting required information from young children, the researcher chose to use observation methods in order to understand their behavior while playing the game. The researcher was not involved in the process, but served as an observer, watching and listening to the activities of children.

Observation method can collect data by observing users' experience with a product [42]. Children were asked to play freely and perform a series of tasks with See Me Roar in competition version and collaboration version. A video camera was used to capture children's action, behavior, facial expression, and comments they made when interacting with the game.

In order to guide the researcher what to observe during the testing and reviewing the video, an observation form was needed [43]. Based on the existing observation scheme [44, 45], the observation form consists of 2 parts:

- Children's affective features when they were playing the game.
  - Positive affect: smile, laughter, clapping, jumping, moving, winning arm gesture
  - Negative affect: sadness (frown), anger, closing eyes, covering face, head down
- Social interaction during the game.
  - Connectedness: hugging, touching, hitting
  - Responsiveness: chair moved, eye contact
  - Compliance: accepting a certain or uncertain proposal

Besides the non-verbal behavior being recorded and analyzed, the verbal emotional responses of the children were also recorded. All the narrative and descriptive data were recorded in the observation form

Semi-structured interview

Upon completion of each version, children participants were interviewed with a list of questions and several probes. As the interviews were semi-structured, the questions that followed aimed at deepening the answers that the participants gave to the previous questions [46]. The interview guide was developed from the instruction of Chauncey Wilson [47], with two probes to trigger more conversation and get more details.

The first probe was the Game Experience Questionnaire (GEQ) [48], which contains multiple questions asking about the game's endurability, the engagement, and social presence in the game. To evaluate the children's social experience and perception of relatedness, the researcher chose the questions from the social presence module and applied them as questions during the interview.

Another probe was Inclusion of Community in Self Scale [49], a single-item pictorial measure of community connectedness. By choosing the self-scale, children could give an overview evaluation to describe to what degree they felt related with the partner. In this scale, the distance of two circles means the relationship between the child and the other(s) (Figure 6).

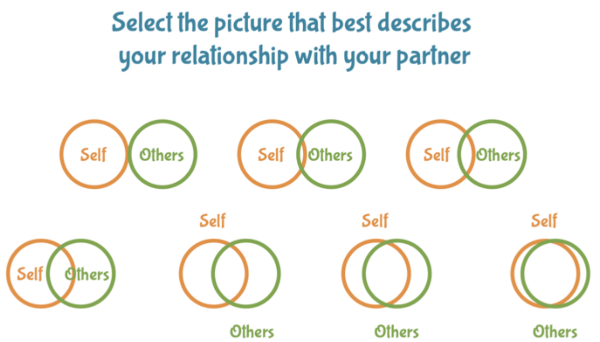

Figure 6. Inclusion of Community in Self Scale

Setups of the User Test
The user test was carried out at the children's houses located in Eindhoven, to provide a relaxed environment for participants. Even though two groups of participants were tested in two different houses, the procedure was strictly the same.

This is the materials and equipment prepared for the user test:

- Informed consent form
- The prototype of the game
  - two tangible textbooks
  - two Samsung Galaxy S8 with Android system 8.0.0
- Video camera
- Observation form
- Inclusion of Community in Self Scale

Participants
The researcher has recruited 4 primary students at the age of 8-12 as the participants who can understand the elementary math contents well. The researcher has also considered the characteristic of children in this age range. For instance, they can easily sit down follow the instructions from adults, and they can describe the things they see and do.

The participants were divided into 2 groups, with 2 children in a group. Table 4 shows a demographic overview of the participants.

Participants	Age	Gender	Group
P1	9	female	1
P2	10	male	1
P3	9	female	2
P4	12	female	2

Table 4. Demographic information of participants

Procedure
This is the procedure of the user test:

- Step 1: Before informing the participants with the goal, duration, and format of the user test, the researcher engaged them in some small talk, in order to establish a relationship with the children and ease them into the next testing. Their parents also needed to sign the consent form in this step, because ethical considerations should be always taken into account.
- Step 2: In the first version of the game, children were asked to scan the maps on the textbook and finish the exercises. When the participants were playing the game, their behavior and verbal communication were recorded by the video camera.
- Step 3: After the participants finishing all the exercises in the first version, there was a semi-structured interview based on a list of questions, as well as their behavior while playing the game.
- Step 4: The participants experienced the second version of the game.
- Step 5: A semi-structured interview was conducted with the participants in the same way.

Figure 7. shows the scenario of user testing.

Figure 7. User test

RESULTS
In this section, the researcher will present the results from the Inclusion of Community in Self Scale, the observations of the participants during the game, and the results from the semi-structured interviews.

Results of the Inclusion of Community in Self Scale
Table 5 below shows the scores of the self-scale (7 is the most relatedness, 1 is the least relatedness). From the result we can see, all children rated collaboration (average score 6.5) with higher relatedness scores than the competition (average score 4.25). To be more specific, all girls rated 7 for

collaboration. One girl rated 2 for competition. The researcher also noticed that for the girl who has better math skills due to the age differences and the boy, the scores for competition and collaboration were relatively close (6 vs. 7 and 4 vs. 5).

	Competition	Collaboration
Group 1		
P1	2	7
P2	4	5
Group 2		
P3	5	7
P4	6	7
Average	4.25	6.5

Table 5. Children's participants for the Inclusion of Community in Self Scale

Observation Results

The researcher also observed children's behaviors during the user study. Here are the key findings.

First, for group 1 (boy vs. girl), in the competition version, the boy had more positive behaviors compared to the girl since he won most of the games, while the girl remained quiet for most of the time and didn't inform the researcher after she had finished the exercise. As for the social cues, the boys were more activated in the competition version. Once he had finished his exercise, he would turn to the girl and helped her if she had a problem. However, in the competition version, they only smiled to each other once at the beginning, and they talked about the game elements once (when the boy saw two elephants in the game, he asked the girl if she also picked the elephant). Apart from that, they didn't communicate much about the game itself during the play.

In the collaboration mode for group 1, more positive behaviors were noted for the girl. She was more active, smiled more, and talked more about the game. Regarding the social cues, they communicated more than the competition mode since they had different responsibilities and had to give information to each other to finish the exercise. (e.g. once the girl was the one who saw the exercise and the boy saw the answers. They communicated about the exercise since the boy did not see the answer the girl gave in his screen. They also discussed about the animal characters several times during the game (e.g. the girl checked with the boy which animal he would choose).

For group 2 (9-year-old girl vs. 12-year-old girl), in the competition mode, the older girl smiled and cheered after she won each game, while the younger girl was excited to see different animals in the game. As for the social cues, the older girl would look at the younger girls' screen after she won the game and showed off to her. They checked with each other every time before the game started to make sure that they started at the same time. The younger girl also raised a demand to play alone for several times without her partner because she wanted to get the correct answer as well. During the game, they communicated mostly about the winning and losing of the game.

In the collaboration mode, the two children were both excited and happy after hearing the collaborating rules. They communicated which animals to select, they decided together where to move the animal, etc. Besides, the younger girl showed more positive feelings after their team got the correct answer and even swayed her body several times.

Interview Results

After experiencing each version of the game, participants were asked some questions about their behavior and opinions towards the game.

Why did you give the scores in the self-scale?

In this question, children were asked about the reasons for the rating in the self-scale.

In group 1, children didn't feel close to each other in the competition mode (e.g. P1: "I want to play the game with others sometimes, but sometimes I want to play alone"; P2: "It feels like I didn't talk too much in the game, only a little bit, not too much. So I rated in the middle"). When asked about the reasons of giving a higher score to the collaboration mode, P2 attributed this difference to how many conversations they had during the game (e.g. P2: "I talked much more this time"). P1 thought the teamwork to finish the game made them more related to each other.

In group 2, children felt that the competition mode could enhance their intimacy, while they were still separated in the game (e.g. P4: "The game can enhance the relatedness itself. But you and she are still separated not the same person."; P3: "I feel like we were half intimated, like what she said, we were not bonded together"). When asked about the reasons why they rated the collaboration mode with higher scores, children expressed their feelings that they were more closely bonded in the game (e.g. P4: "When working on the group activities, she and I were united").

How fun were the different versions of the game?

Each child was asked to rate the game experience on a scale of 1 to 10 in terms of the degree they had fun. Except one participant (P2), the other 3 children gave higher scores on the collaboration version game. For the reason of giving a different rate, children have emphasized on different aspects, such as taking turns bringing a different experience, teamwork, difficulties of controlling animals, and sense of responsibility.

In group 1, both children rated the competition version with a score of 8. The competition version was preferred by the boy (P2: "I think the competition was more fun"). While the girl preferred the collaboration version with a score of 10 (P1: “I like that kind of game, teamwork, that’s very fun for me”.) The collaboration version also had benefits of taking turns according to the children (e.g. P1: “I gave it a higher score because you can take turns”; P2: “The fun part of the collaboration version was that you could take turns”).

In group 2, The younger girl (P3) rated the competition version with a low score of 5, while the older girl (P4) rated the competition version with 9. P3 mentioned the factor of "win" or "lose", which would affect how she rated. (P3: "If I have won more times, I would give it a higher score"). Both of the children rated the collaboration version with a score of 9. According to the children, the feeling of teamwork made them feel more immersive and engaged in the game (e.g. P4: “I think both two versions are nice. In collaboration, I felt like in a team so I could not take my team slow. Collaboration made me feel more responsible, so I wanted to win better than the competition version. Collaboration made me engage more, even though there was no winning or losing, I wanted to make the things right”).

What was your perception of interacting with your partner?
Children were asked a list of question about how they perceived the interactive behavior with the other child, including gazing at the partner's phone, feeling shy to communicate with each other, eye contact, and the possibilities of being affected by the partners' mood.

All the participants said they saw the partner's phone quite often in both versions, because they wanted to know the process of the partner so that they could win the game, or just to check whether their calculating answer was correct in collaboration version. There was also a condition that the more skillful child taught the partner how to operate (e.g. P2: "Because I saw she could not scan the page"). None of the participants thought they would feel shy to talk with the partner in both versions.

As for the mood affection, both of the participants (P1, P2) of the first group said their moods were affected by the game instead of the others, while the second group members (P3, P4) held a totally different attitude (e.g. P4: "The atmosphere between us is very important.")

DISCUSSION
In this paper, the researcher presents a co-design session and a user study to explore the social elements in an AR-based game for mathematics learning. Although the numbers of participants were limited in this study, from the results the researcher found some trend and insights.

Co-design as Input for the Game Concepts
The current game prototype was designed and developed based on the output from the co-design sessions. The researcher found that animals were highly appreciated by children. They praised the choice of various animals and the concepts of animals eating food and food chains.

From the results of the user study we can see, children showed a lot of interests in seeing different animals and selecting animals during the game. They were excited to walk their animals around the textbook. What’s more, the competition and collaboration versions were also adapted from children’s ideas for multiplayer games. During the co-design sessions, one child designed an idea of competing for the animal’s speed of eating food, while other children have presented the tasks that can enhance the collaboration by giving children different responsibilities. The researcher has applied both ideas of competition and collaboration in the game prototype. The results of the user study showed that children had different preferences on these two versions.

In summary, the output from the co-design sessions did in line with the user study, which positively influences the design of the prototype. Hence, the researcher sees the benefits of involving children’s perspective in the early design process for children.

Collaboration as the Element in See Me Roar
From the result of the user study, the researcher found that all children rated the collaboration version with a higher level of relatedness than the competition version. Children had a strong feeling of teamwork, felt bonded and responsible to perform well in the collaboration game. Hence, the researcher sees that the design of the collaboration game in See Me Roar has the potential to facilitate children’s perception of relatedness.

From the observation result, the researcher found that children had more positive social behaviors and attitudes during the collaboration version compared to the competition version. Children found the design ideas of different responsibilities and taking turns were fun in the collaboration. Therefore, it can be seen that collaboration could improve children’s motivation in the learning process.

Specially, girls rated collaboration with more relatedness than competition compared to the boy. This result is consistent with the co-design session, where the boy designed for a competitive game for food-eating. In the primary school years, boys and girls might have different interests, especially in subjects like mathematics.

What’s more, in our user study, the older child has more math skills compared to the younger child. From the perspective of the younger child, who could represent the child with lower math skills, found collaboration more fun than the competition version since there was no winning and losing for her. Different children have different learning abilities. In the social learning environment, children could be demotivated due to the fear of failure, etc. With the collaboration version, there are opportunities for children to help each other where they might be shy to ask questions from their peers or teachers in general situation. Hence, collaboration version could be helpful to enhance communication among children and encourage children with different learning abilities and skills.

Competition as the Element in See Me Roar

Although collaboration might trigger a higher level of relatedness, there are some interesting opinions towards competition version in the game.

One child thought that the competition game could enhance the relatedness, but they were still separated. One child stated that there was a lack of communication in the competition game. However, when asked about the preferences of two different versions, the boy rated the competition game with higher preferences with more fun. While the younger girl who has fewer math skills wanted to play the same game for several times in the competition version to win the game spontaneously. Hence, competition game could also motivate children in the learning process. There are different types of game players, including competitors and collaborators. Children should have the freedom to choose the game they like to play. This is also included in the SDT as autonomy where users should feel like they have the choices by themselves instead of being controlled. Therefore, competition game might motivate some children and should be kept in See Me Roar.

Limitations

There are several limitations of the study that need to be addressed to further explore the social elements in See Me Roar. First, in the co-design session and user study, the children have different ages due to the resource's limitation. Second, the sample size for this study is low. Future work should increase the sample to increase generalizability for the current findings.

CONCLUSION AND FUTURE WORK

Social elements can improve the motivation of children in their learning process. It is important to study which social elements can improve the perception of relatedness and their effect on children's motivation. This study was built on the SDT to explore the effects of collaboration and competition on the relatedness and motivation level on children's learning process. The researcher conducted two co-design sessions with four children and four designers to come up with game concepts. The game materials and prototypes were designed and developed based on the results from the co-design sessions. The researcher conducted two groups of user studies with four children with the game. From the results of the user study the researcher sees the potentials of applying the current collaboration and competition game versions in See Me Roar. The researcher also found that children might have different preferences towards different social features, especially between different genders and learning skills. Thus, it is important to keep different choices open for children to fit.

In the future, the researcher would conduct the user study with more groups of children to have a better understanding of the quantitative data.

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