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# A Case Study of Mobile Game Based Learning Design for Gender Responsive STEM Education

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***Abstract*—**Designing a gender responsive Science, Technology, Engineering and Mathematics (STEM) mobile game based learning solution (mGBL) is a challenge in terms of content, gamification level and equal engagement of girls and boys. The goal of this case study was to research and create a high-fidelity prototype design of a mobile game that contains role-models as avatars that guide and expose girls and boys to STEM learning content. For this research purpose it was applied the methodology of design sprint with five-phase process that combines design thinking principles. The technique of this methodology comprises smart interviews with STEM experts, mind-map creation, sketching, prototyping and usability testing of the interactive prototype of the gender responsive STEM mGBL. The results have shown that the effect of the avatar/role model had a positive impact. Therefore, by exposing students (boys and girls) to STEM role models in an mGBL tool is helpful for the decreasing of the gender inequalities in STEM fields.

***Keywords*—**Design thinking, design sprint, gender-responsive STEM education, mobile game based learning, role-models.

## I. Introduction

STEM education prepares students for working in the technological and digital professions [1]. A gender responsive STEM education gives equal opportunity to girls and boys in accessing education and careers in STEM fields.

Research suggests that digital game-based learning led to a higher level of educational results, engagement and immersion in learning, improved comprehension and understanding of STEM course content, development of problem-solving skills and critical thinking skills. The progress and evolution of mobile game-based learning has been considered as a new line of research and technological development in the field of educational technologies, STEM education and game design [2].

The mGBL is a digital system that facilitates educational tasks and activities through game-play that are designed for teaching and learning purposes [3].

STEM education should engage and stimulate students to experience the professional practices of STEM in such a way that they can understand clearly which practices and techniques are useful in various different situations [4].

Researchers and educators have been dedicating endeavors to progress and apply new teaching methods and techniques to support the extensive STEM curriculum such as (i) the use of the so called serious games as learning tools (Game based Learning systems); (ii) the design and development of games as a context for learning (Game Development Based Learning); and (iii) the use of game elements and game interaction design techniques to improve the learning experience of students (Gamification) [5].

Mobile game learning has become a good option in the learning model. Mobile game learning uses smart phones and tablets as a basis for running applications so learning content can be accessed using a smart phone or tablet [5]. The mobile learning gives potentiality and practicability to transform the education in the digital era. The STEM educators can use this potentiality for teaching, mixing mGBL and gamification in order to create an educational environment with equal gender chances.

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## II. Background Motivation

### *A. The Current Challenge*

Gender balance is a concept related to equal opportunities for males and females that should have equal chances in all the institutions of the society, namely, religion, economy, education, culture, and policy. Different authors relate gender to exploration of subjects that affect both women and men within a society worldwide. The gender is a social construct that identifies the relationships, expectations, and roles of both males and females [6].

Researchers focus on understanding why the gender stereotypes are important, why there are differing expectations of girls and boys, which part is disadvantaged by these expectations. Some theories from educational and social psychology may support the idea that all children should be exposed to various curricula in schools because they have equal chances to develop and become experts in each existing area [7].

The gender balance should be applied in STEM fields. Those fields highlight in a visible way those gender differences in the practicability of professions in those areas of expertise. The gender differences in STEM are distinguished in early education. Different specialists observed that girls lose interest in STEM in late adolescence and the gender imbalance is more obvious in higher education levels. Performance of women in areas, in which men used to have more access, can be increased if gender balance is applied for the education of the next generations of individuals [8].

Gender responsive STEM education can be delivered by digital technologies like mGBL tool. The digital technologies have become a guiding dimension for the digital learning platforms that will allow and qualify learners in STEM areas with efficient and customized learning experiences alongside with the motivation and inspiration for cooperation in innovative manner that are beyond traditional learning [9].

### B. Significance of Design Sprint in mGBL

Design Sprints represents a fast design model for building applications effectively and efficiently. This model can significantly design frameworks that reduce complexity in creating and developing the mobile games based learning applications [10].

## III. Methodology

This study examined the performance of a mobile game-based learning solution with STEM content for gender responsive education that has been created based on Design Sprint techniques.

Designing an mGBL solution with roles models that impact and stimulate the participation of girls in STEM fields as a solution for gender balance is challenging.

The workflow of the mGBL solution consisted in five phases: understand, diverge or sketch, decide, prototype and validate. This mGBL tool can be considered as important solution to foster learning for girls and boys in STEM fields.

The instructional content was exposed on tablets and has the purpose to build up a successful learning experience guided by role models from different STEM fields. The students have the capacity to understand that both males and females can be successful in STEM careers based on the principle of observation and modeling the performance of role models.

The educational content has gamification elements and reward system for the performance of students which facilitate the engagement and immersion in the instructional game.

## IV. Results

### A. mGBL Design for Gender Responsive STEM Education

An mGBL solution like this framework design is a strategy for alleviation culture-related factors that affect the participation of girls in STEM education. This framework can be used as a guide for STEM lecturers as educational tool to eliminate gender-based discrimination during the process of teaching.

The creation of the mGBL prototype was based on complex inter-related phases of the Design Sprint methodology. The understanding phase is the beginning journey for discoveries of students' real needs, types of STEM content and strategy formulation for a meaningful learning experience. In the next four phases we have sketched some competing solutions; we have continued to decide, to prototype and to validate the best solution. The validation phase proved that the mGBL solution is engaging and efficient for students to develop their STEM practical skills with both digital and non-digital tasks and experiments.

### B. Understand

The brainstorming of ideas of the team of researchers and designers was the foundation of the process based on Design Sprint methodology and principles.

The context mapping for the research was based on expert interviews from different areas of STEM fields that have deep knowledge about gender-issues in STEM educational and industrial practices.

The insights of STEM experts have guided the team to set the goal of the mGBL solution for the real needs of girls and boys. Different techniques and tools were used for the proposed plan of action and execution. A clear and consistent mind map with refined ideas for the mGBL prototype has been created for a better visualization and management of project development.

### C. Define and Diverge

This phase of define was based on creating a list with few solutions from the related and non-related fields of focus and all data and insights collected from the context mapping process.

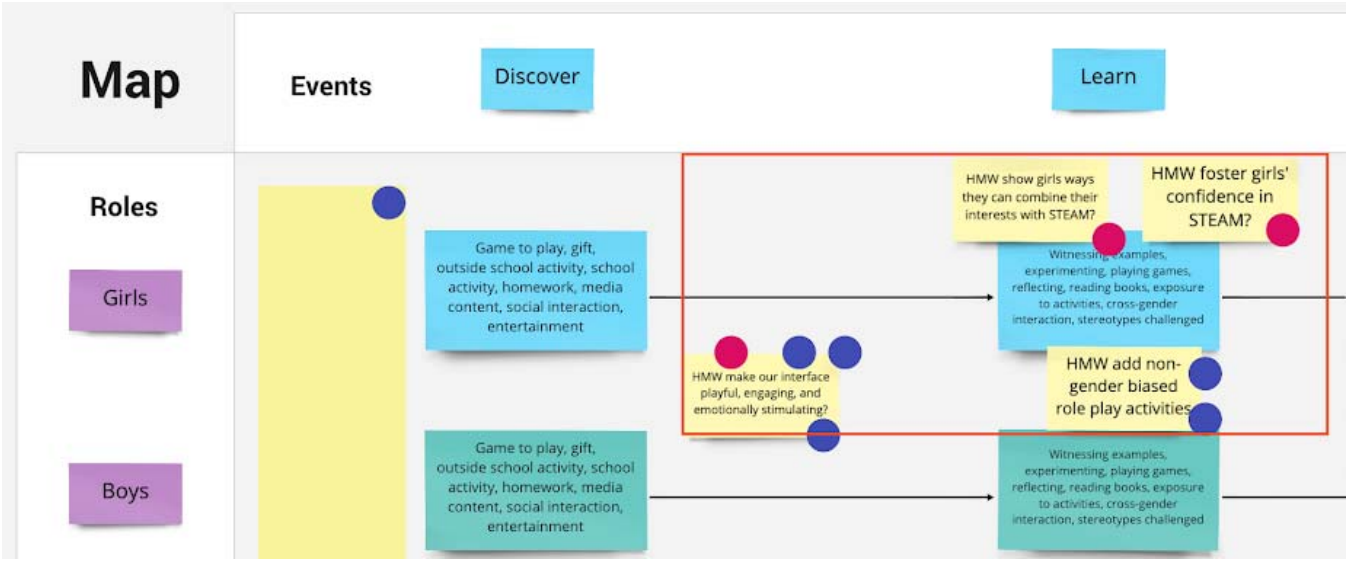


Fig. 1 Mind map with ideas based on needs of users

The team members performed synchronously and asynchronously their tasks based on required techniques. They have created sketches with Sketching Crazy 8's technique and after that the decision process was applied.

*D. Decide*

The decide phase of the methodology have imposed to the researchers to vote the favorite and most efficient solution that shall be prototyped in the end. Techniques like heat map, speed critique as an opportunity for short discussion and clarification, straw poll and super-vote were used to capture the big ideas and create a storyboard. The decision process is an important phase in which the team members vote the most suitable elements for the mGBL design to be included in the storyboard and prototype.

The storyboard is a rough design of the gender responsive STEM mGBL solution for the needs and challenges of end-users (see Fig. 2).

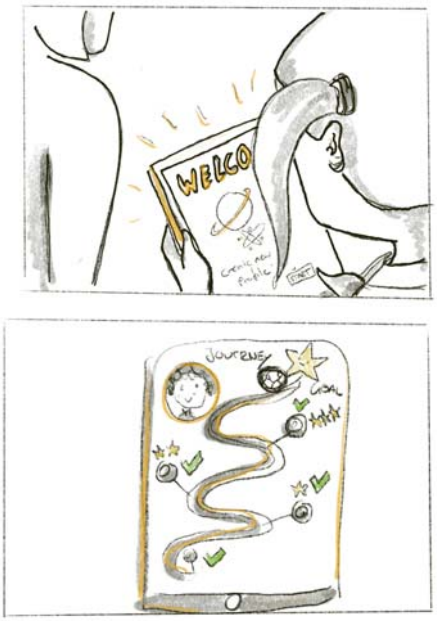

Fig. 2 Storyboard of mGBL solution for STEM Education

*E. Prototype*

The previous stages of understanding, defining, creating and deciding represent the pillars for the low-fidelity and high-fidelity prototypes development of the mGBL solution. The low-fidelity prototype was very helpful for general improvements for the high-fidelity version.

The high-fidelity of the prototype was executed in a graphic editor where the team of researchers collaborated for the creation and iteration. Fig. 3 presents the prototype interface screens that were designed by the researchers. The prototype of the mGBL model comprises input-process-outcome workflow with learning contents (STEM knowledge and information about famous scientists), gamification and game characteristics (avatar as role model, mission, experiments, quiz) and learning achievement (reward with certificate). This study exposed users to learning contents about science, specifically about acidity and volcanoes. The game characteristics provided to users were avatar guideline, rules and challenge in the mission of experiments and quiz for knowledge and skill evaluation.

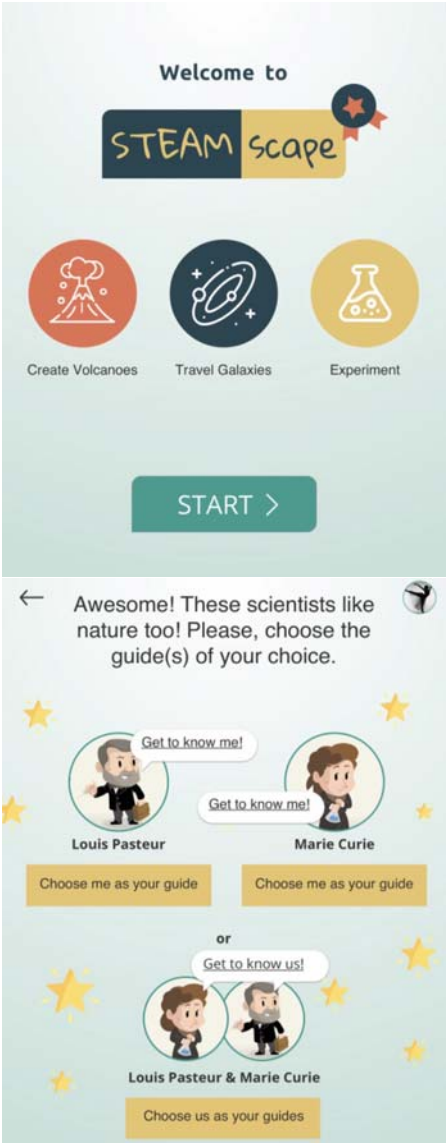


Fig. 3 Prototype interface screens

*F. Validate*

This phase of validation consisted in usability testing and user experience evaluation. The team has decided to use the cognitive walk-through and interview for the collection of deep insights of students. The usability testing was performed with 10 students (5 boys and 5 girls, age range 8-12).

In the usability testing the students were exposed to a roadmap with digital and non-digital tasks and experiments they had to execute. The students have the task to choose one or two role models as guide avatar for their journey in the game. For every task finished the student is evaluated based on which it receives reward points and a final personalized certificate for its performance.

The next step was the affinity diagramming of all observations for a final data analysis. The general results have suggested adding more complex content for all categories of students (like those with visual impairments). The effect of the avatar/role model had a positive impact and it can be considered as key feature or element for this gender responsive STEM mGBL solution. By exposing young students (boys and girls) to STEM role models is helpful for the gender-sensitive issue perception.

## V. Discussion

This paper found the complex Design Sprint methodology as efficient technique for the creation and prototyping of a gender responsive STEM mGBL solution. This prototype is a successful solution for responsive STEM education. It contains innovative elements like customization and pre-upload of photos of users for the gaining of the students's engagement. The augmented reality feature was proposed for better immersion and motivation of students.

The content of the mGBL solution combines digital and non-digital tasks and experiments that guide and teach students STEM skills. The students both girls and boys are tech-savvy users of smart phones and tablets so the user interface of the educational game was easy to be used and efficient for their performance.

The importance and necessity for students to learn from the tasks with problems from the real world have been highlighted by educators [11]. This mGBL solution with instructional content for STEM fields based on tasks and experiments with problems from the real world and guidance of role models can enhance the performance and improve the creativity of students.

## VI. Conclusion

This paper presents the case study of a gender responsive STEM education mGBL prototype based on Design Sprint methodology with five phases. This methodology is useful in designing and prototyping an mGBL solution for STEM education.

The understanding phase collected important information from STEM experts for the context mapping of users' needs. The defining and diverging phase has focused researchers and designers on sketching and proposing more solutions and choosing the best one for the mGBL framework design.

The input-process-outcome workflow was used for the instructional content mixed with gamification and game elements and characteristics (avatar as role model, mission on the learning journey map, experiments, quiz and reward certification) in the prototyping phase.

The final phase of validation explored the students' insights and experience in the usability testing sessions. The role models as part of the educational content in the mGBL prototype proved to be positively impactful in the young student's perception.

The role model avatars that guide the students through the learning journey can represent a key factor for an efficient gender responsive STEM education. The students, both girls and boys need to be exposed to female and male role models in order to cultivate the awareness of a mindset in which both women and men can study and perform in STEM fields.

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