Design Factors for an Educational Game Where Girls and Boys Play Together to Learn Fundamental Programming

Peter Mozelius[1] and Niklas Humble[2(✉)]

[1] Department of Communication, Quality Management and Information Systems, Mid Sweden University, Östersund, Sweden
peter.mozelius@miun.se
[2] Department of Computer and Geospatial Sciences, University of Gävle, Gävle, Sweden
niklas.humble@hig.se

Abstract. Gaming is a ubiquitous phenomenon today, and game-based learning has become a main stream teaching and learning activity. Despite the long history of using games in educational contexts, the concepts of inclusive game design and enjoyable educational games still have challenges. The aim of this study is to gather requirements for design of educational games on programming where girls and boys find it joyful to play together. To meet this aim, the data sets from two earlier studies have been combined, compared, discussed, and finally merged into a preliminary framework. This study was carried out as a requirement-focused design science study, with a focus on gathering requirements for a future design and implementation of an educational game on fundamental programming. Data were collected in a combination of a scoping literature review, and through a questionnaire answered by elementary school students after playing an educational game on programming. Main themes in the framework for Girl Inclusive Educational Game Design are Exploration Without Violence, Collaborative Interaction, Character Diversity, Customisation, Graphics, Game Mechanics, Game Content, and Learning and Motivation. If these factors are thoughtfully considered it could be possible to achieve the idea of a game with Wide Walls, a High Ceiling, and a Low Threshold, where girls and boys could play together and learn how to program.

Keywords: Game design · Inclusive design · Gender inclusion · Educational games · Programming education

1 Introduction

Several research studies have reported on the labour market's increased need for professionals with programming skills [1, 2]. Programming courses are an important, but also challenging part of the future computer experts' education process [3]. To meet the demands of the labour market and society, a global trend is to integrate programming in elementary school [2, 4]. With this younger learner group there is also a need

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for new didactic methods, curriculum development, and a more joyful learning process. An old concept for motivation that has got a digital renaissance during the last decades is game-based learning (GBL) [5]. GBL has also been used frequently with promising results in science, technology, engineering and mathematics (STEM), and in programming education [6, 7].

The use of games for educational purposes has been around for thousands of years, and long before the appearance of digital video games in the 20th century [8]. In the 21st century the so-called casual revolution [9]. Gaming has become a ubiquitous activity, reaching a wider target group than ever before. Many children are spending a considerable amount of time today, playing a wide variety of analogue, digital and hybrid games. Another contemporary phenomenon is that the games in educational contexts now are established as a mainstream teaching and learning activity [10], with game-based learning becoming a support tool for students with special needs [11].

Despite the progress in inclusive game design girls and women have not embraced videogames to the same extent as boys and men [12, 13]. Research studies have also reported that certain types of games are more appealing to girls than others, and with an identification of game concepts that females find repelling [14, 15]. Furthermore, certain types of gameplay have been pointed out as more appealing to boys than to girls [14, 16]. The use of educational games on fundamental programming has a potential to bring about active learning in classroom activities [17], but there are gender issues to consider in game-based programming education [18, 19].

The research gap that authors try to address in this study is two-folded. Firstly, to investigate which particular game details that make girls feel welcome to a game, and also to identify the details that have the opposite effect. Secondly, it is interesting for a future game design to get the elementary school students' perception on design factors for an educational game on computer programming. To merge these aspects into a comparative analysis and common discussion, authors have combined the data sets from two earlier studies [20, 21]. Authors hope that the combination of a literature review and student answers to a questionnaire, should result in design factors useful in the future implementation of educational games. With a design science approach, the aim of this study is to collect requirements for design of educational games on programming where girls and boys find it joyful to play together. The research questions that guided this study were: RQ1: "Which specific design factors are important for a girl inclusive game design?", and RQ2: "What are elementary school students' perceptions of important design factors for an educational game on computer programming?".

2 The Development of a Game Prototype

The game development tool RPG Playground (RPGPlayground.com) was used to design and develop an educational game prototype. RPG Playground is a free game development tool enabling game developers to create web-based role-playing games (RPGs). Games created with RPG Playground can be played on computers, surf tablets and on mobile devices, which can be important options for elementary school teachers. The game 'Escape with Python' was developed with the idea of creating a digital escape room that students would find joyful and motivating. The idea of an escape room with

challenging problem solving has been tested with positive results in computer science [22, 23]. Escape with Python was developed with a clear focus on fundamental programming in the Python programming language. Game content, (the challenges in the escape rooms) was constructed with a deliberate close alignment to the programming content in the syllabus framework for elementary school that was created and distributed by the Swedish National Agency for Education [24] (Fig. 1).

Fig. 1. Escape with Python – opening scene (Graphics by Niklas Humble)

Five fundamental programming concepts were chosen from the syllabus framework to constitute the basis for the problem solving in the escape rooms. The chosen concepts were variables, sequences, conditions, iterations, and functions. Each of the programming concepts presented are part of the problem solving in two escape rooms. In the first escape room for the actual programming concept, the player is guided through the solution facilitated by metaphors from everyday life. In the second escape room for the programming concept, the challenge increases with complex tasks that has to be solved with less guidance [24].

3 Method

This study was inspired by the design science idea that has been described as a problem-solving paradigm that seeks to innovate ideas, practices, and artefacts [25]. The overall

goal of design science is to produce knowledge in the field of design, and knowledge that have a potential to support problem-solving in the design [26]. A design science approach by Johannesson and Perjons [27] was used to structure this study in five discrete but interrelated steps: 1) To explicate the problem, 2) Defining the requirements, 3) The design and development of an artefact, 4) Demonstrating the artefact, and 5) To evaluate artefact.

Many design science studies do not carry out all the five steps in the design science method framework, and the focus could be on one or two of these steps. This study was carried out as a requirement-focused design science study, with a clear focus on defining requirements for the future design and development of an artefact. A requirement-focused study starts with an existing problem, and defines requirements in a combination of a literature study, and interaction with a purposive selection of key stakeholders. In requirement-focused design science research the artefact design should be outlined, but not implemented, demonstrated, or evaluated. [27]. Despite the narrow and specific research design, the results from this literature review could hopefully generate a more general knowledge that can be useful for future design and implementation of educational games.

3.1 Data Collection

Data were gathered in a combination of a scoping literature review, and through a questionnaire that was answered by elementary school students that had tested the Escape with Python game.

The Scoping Review

This part of the data collection was conducted as a scoping review to provide an overview of a specific topic of interest [28]. The scoping review approach has been recommended to use when the selected topic is complex or heterogeneous, and when a study has the purpose of identifying knowledge gaps and to clarify concepts [28, 29]. Furthermore, a scoping review is a method to identify the main sources and to find key concepts in a specific research field [28]. This scoping review strived to synthesise research results to gather requirements for a specific target group, as a foundation for future research. Considering the type of literature review and the aim of the study, the research question was formulated concrete to support the chosen research design.

The main search engine to identify research papers of interest was Google scholar. Search strings were combined with the use of Boolean operators OR and AND, based on the main keywords Games, Inclusive, Design, Girls, and Women. The literature search was deliberately wider than the scope of games on programming to not exclude or miss important and relevant design factors from other types of games. Moreover, backward and forward searches were used to identify seminal research publications that have a potential to contribute to answer the research question. After a critical rereading of the result set, 24 research publications published between 1994 and 2022, were selected for a further thematic analysis.

Game Demonstration and Questionnaire

The game protype for Escape with Python was demonstrated and evaluated by 32 elementary school students during the autumn semester of 2021 and the spring semester of

2022. Data were collected by a questionnaire containing a combination of closed-ended, and open-ended questions. This study has only used the answers to the open-ended questions with feedback on the perception of playing the game, and suggestions on how to improve the game design. Game testers were recruited by an open invitation announced in the virtual learning environment for a professional development course on programming for primary and secondary school teachers. Four teachers responded to the invitation and wanted to test the game together with their students. The questionnaire was sent to these teachers together with a form for informed consent to be distributed among the testers.

Only two teachers were able to carry out the complete testing, and to return the questionnaire answers. One of the teachers used the game as part of a structured introduction to programming, while the other teacher played the game together with students that had showed a general interest for computer programming. From a total of 32 students, 28 where from grade 9, 2 students from grade 8, 1 student from grade 7, and one student that did not specify. Regarding the gender distribution, there were 18 boys, 11 girls and 3 students that did not specify gender. The game was tested in the subjects of technology (23), mathematics (4), and programming (3).

3.2 Data Analysis

Both data sources were thematically analysed guided by the six-phase process outlined by Braun and Clarke [30]. The first phase had a focus on immersion and to get familiar with the data, in an iterative reading of the data sources. In phase two the more systematic analysis started, involving the creation of initial codes and writing memos on interesting concepts. The next phase contained the collation of codes and subcodes into preliminary themes. Phase four handled the review of the preliminary themes, and checking if the themes work in relation to the coded extracts and if themes should be merged or split into new themes. This work continued in the fifth phase with a fine-tuning of the definitions and naming of the themes. In the final sixth phase the presentation of the found themes is written with a focus on details that have a potential to answer the research questions.

4 Results and Discussions

The results from the two different data sources are first presented separately under 4.1 and 4.2, and finally compared and merged under Sect. 4.3.

4.1 The scoping review

Five main themes were identified in the analysis of the literature search. The first four themes are considered important design concepts for a girl inclusive game design. In contrast to the last theme that shows potential problems with a too girls specific design that might exclude boys. The identified themes are presented and discussed under separate sub-headings below.

Creativity and Customisation

The first found theme was that girls have expressed a more positive preferences for games that encourage creativity, were creativity could be features for modifying game characters and game elements. Girls also appreciate the possibility to create artwork for use within or outside the game [31]. Moreover, it has been pointed out in the study by Spieler and Slany [32], that girls playing a game spend much more time creating artwork than to gather game points, when compared to boys playing the same games. Girls obviously prefer to create, modify and to play without the violent feedback that appears in combat games, when boys seem to have the opposite preference [33, 34]. As recommended in the study by Fullerton et al. [35], there should be a possibility to change the games world and, harder to implement, that play and players could have a positive impact on the surrounding society.

The study by Sharma et al. [36] highlighted that many girls appreciate functionality in games that enables them to customise elements in the game world. This could be seen as something that enables girls to express themselves, and to show their preferences [37]. This kind of activities are something that girls can became fully engaged in [38]. An example of a game where customisation and creativity are larger parts than the actual gameplay is the Sims game series [35]. Most of these games in the Sims series lack the clearly defined game goals, that is part of the definition of a game, and have been classified as digital doll houses. In the Sims games, a virtual character can get sad, moody and also depressed if they get too isolated from the other Sims.

Exploration Without Violence

An identified difference is that boys are more attracted to games with combat and violence, while girls prefer non-violent competition [39, 40]. This difference has also been reported in studies on game creation. The study by Spieler and Slany [32] found that boys built significantly more shooter games, compared to girls that instead preferred to build role playing games. Moreover, it has been emphasised that girls have a stronger tendency to design games with both male and female characters, and with more options to choose different game avatars [33]. These game creation studies have also reported on differences in the feedback design. Studies have pointed out that girls in general build games with little violence or punishing feedback, while boys more often create game features with violent feedback [33, 34, 41]. In a recent study by Dilmaghani [16], it was presented that female chess elite players' attitude towards competitive chess is shaped by the belief that they have something to prove to male players. A statement that origins from the Woman Grandmaster (WGM) Jennifer Shahade [42], and her observations of female chess players elite tournaments. However, it could be argued that the rather low percentage of females in the chess elite, consists of the girls that are more competitive than average. Chess has a clearly higher percentage of male players in all age groups.

Girls prefer exploration and collaboration to violence, and that the game should be challenging in realistic settings with sophisticated graphic and sound design [41, 43]. Furthermore, studies have reported that girls want a more explorative gameplay with a rich narrative, diverse activities and characters, to be combined with social interaction [44, 45]. Some of the studies in this section were conducted over two decades ago, but the high degree of violence in digital games still remains. Not that surprising, but the balance seems better in the domain of educational or serious games.

Collaborative Interaction

The studies on children creating games also points out that boys to a higher degree liked to build competition and combat games, while girls were more interested to build games with social interaction. In the early landmark study on the gender differences in game design by Kafai [46], it was found that girls created games with a higher degree of social interaction, whereas boys chose to create games with combat interaction. Miller, Chaika and Groppe [43] also reported from their focus group discussions that girls preferred games with collaboration, instead of combat games. Several other studies have pointed out that girls in general want to play games with social interaction related to a rich narrative with sophisticated game characters [44, 45]. As concluded by Dickey [41, p. 78]: "There are many commonalities between most of the studies concerning female-oriented design, but the most notable is the importance placed on collaboration and community."

One of many different ways of sorting games into genres is to group them as competition games, combat games or collaboration games. Findings from several studies indicate that boys fancy combat games [32, 33], whereas girls prefer a game design that involves collaboration [41, 43]. Competition games are in-between, and as stated by Taylor [47], girls like competition games, when the competition is combined with collaboration. This could be compared to how Comenius, in the 17th century, described how he wanted to combine peaceful and serious gaming with collaboration and competition to stimulate the learning process [48].

Character Diversity

As highlighted in the seminal studies by Kafai [33, 46], girls prefer games with both male and female characters, which also is reflected in games design where girls more often creates both male and female game characters. Girls also seem to like non-gender-specific characters in realistic settings [41, 46], if compared to boys. In a recent study by Leonhardt and Overå [49, p. 7] it was posited that "Both boys and girls were critical of gender representation in video games", and around 25 years after Kafai's studies the unbalanced gender representation seems to remain. Or as formulated by a 9th grade girl in the same study: "The characters in video games are mostly guys. There are lots of war games. I don't play any video games where the main character is a man". This girl described herself as having gaming as a passion, but at the same time being reluctant to many digital games since they lack "good female characters". Another girl, in the same study, mentioned the passive and helpless princess character in the Super Mario games to be an example of an uninspiring female character [49, p. 7].

Girls need inspiring female role models, and as pointed out by Spangenberger et al. [50], in games with female protagonists, girls got more interested in technical subjects after playing this type of games. In a study on educational games to learn computer programming, two of the games were intentionally designed different. The first game was designed to be truly gender neutral, while the second game had a clearly girl-oriented design. The conclusion from the study was that both games were equally effective to reach the learning objectives, but that the players that had a preference for girl-oriented games, were stronger motivated to learn computer programming when playing the girl-oriented game. [51] This contradicts the conclusion from the study by Kafai [46], where it was stated that girls prefer non-gender-specific game characters. An interesting contradiction

that bridges over to the next theme 'Gender specific game design', and at the same time relates to the first theme, 'Creativity and customisation'. As pointed out by Sharma et al. [36] in a study on design of serious games for girls learning about computer science, personalisation was one of the most desired design factors in the games. Moreover, it has been claimed that personalisation could motivate girls to see themselves as role models [36, 52]. Maybe customisation and personalisation are key concepts for inclusive design, and in more aspects than the one of gender?

Girl Specific Game Design

Another approach to address the challenge with getting more girls and women into games and game design is through gender specific design, and to create a so called "virtuous cycle" [35]. Girls and women might be more interesting in playing and creating games if there would be more games that appeal to girls and women. Resulting in more games would be created by girls and women in a positive circle with an iterative increase of appealing games [35]. However, games that specifically appeal to women and girls alone, will not necessarily result in more female game designers, and men and boys could feel excluded. As an example, a girly game with a gameplay about designing dresses would probably appeal to many girls and women, but will likely not make them choose an engineer career [41, 53]. Moreover, it may be advised to offer both girls and boys the opportunity to explore areas that they normally would not be drawn towards. It also seems possible that girls could appreciate active gameplay, and that boys can enjoy a more creative gameplay [31].

In the choice between a gender specific design, and an inclusive design, the choice must be an inclusive design. A metaphor for this could be the wide walls concept in the Scratch programming language, the walls should be wide enough to engage people with many different preferences, and different learning styles in the same learning environment [54]. Finally, as brought up by Dondlinger [55], the presumption that girls and women differ from boys and men in gaming habits, such as it is not done with the same intensity and duration, has little empirical support.

4.2 Questionnaire Answers

The answers to the open-ended questions contained many interesting perceptions about the game, and also constructive suggestions for improvements. Results from the thematic analysis are presented under the sub-headings here below.

Game Graphics and Customisation

Answers indicate that students liked the retro-feel of the game, and that it resembled other games that they had played earlier. On the other hand, there were more critical comments as well and some students asked for an overall design improvement. They suggested more details in the rooms, a better general quality for graphics, and background music. As discussed before in other studies on educational games, it is hard for projects in academia to compete with commercial AAA games regarding graphics [56]. However, some students appreciated the minimalistic design of the game, and wrote that they liked that they easily could keep an overview of what they were doing in the game. Finally, it was suggested by the students that every player should be able to customise their game

characters, and to take control over how they were visually represented in the game (Quote 1). "Good, the design was simple and you did not get overwhelmed. But you should be able to do customisation on the character that you play and design its' look. Or, if there were other worlds that you could travel to." **Quote 1**. Student about graphical design and customisation of the game.

Game Mechanics and Customisation

The results from the analysis also show that many students perceived the gameplay as unclear, and that the gameplay lacked consistency. An example is that the problem-solving approach in one room did not reoccur in the next (Quote 2). This raises the question if it would be good didactics to always solve problems in the same way, which would be a repeating routine in this type of game. It can also be argued that problem-solving in programming is versatile, and that a skilled programmer needs a toolbox rather than a tool. On the other hand, some students wrote that the game was easy to play and understand. These variations could probably be explained by the students previous gaming habits, and to which extent they have played different types of games. Like the comments on customisation in the previous section, some students suggested that the gameplay should have more freedom and choices. For example, players should be able to explore the game world more freely, and also with features for writing code in the game, instead of selecting pre-written code. This would require a more complex implementation of the game, but also open up for stronger learning outcomes. Moreover, there was also expressed that the dialogues with non-player characters were appreciated, but that they were presented too slow. "In some rooms you used those glowing things to do stuff but in other rooms you walked up to some character to do stuff. It feels a bit inconsistent." **Quote 2**. Student about gameplay and game mechanics.

Game Content

As for many other game analyses, results show that players have strong variations in their perceptions of the level of difficulty. The most probable explanation to this, is the player's prior experience of programming, which have variations in the testing group. Furthermore, there are comments on that the presentation of code and instructions in the escape room dialogues should be improved. Students bring up that there are too many dialogues to read, and that that the codes were difficult to understand when they were presented in a game dialogue. Students also pointed out that it was difficult to remember all details that are needed to solve the problems in the escape rooms. Moreover, some students suggested that the game could be made more exciting by adding a 'life-system', which would inform about the number of chances that the players have for solving a problem (Quote 3). This would be an improvement that also address the issue highlighted by some students: It is possible to cheat or guess your way through the game, since there are no penalties for wrong answers or wrong choices. "I think that the game should have some sort of life-system. Because you can test all the answers without consequences. You don't really have to think to finish the game." **Quote 3**. Student about the content and the challenge of the game.

Learning and Motivation
Last but not least, learning and motivation, where an educational game without learning hardly could be called an educational game. In addition, an educational game that do not create motivation would never be a decent alternative to traditional teaching and learning. One of the most positive findings was that students expressed that they found the game engaging, and that they at the same time had learnt something. There were other positive comments on that the game content was related to school content, and that they saw the game as useful. Moreover, students expressed that they learnt about loops, thinking iteratively, and to being precise and accurate. Regarding motivation they mentioned that they want to learn more about programming, and how to create their own games. This touches upon the other aspect of game-based learning for programming education: learning to program by building games as a complement to learning by playing [57]. Some students expressed that they found programming to be difficult, and that it requires too much work to learn programming. Programming has been classified as problematic learning, but this might be addressed with more of the in-game explanations and hints, which also was suggested in the questionnaire answers.

To get everyone aboard in an average elementary school class, the idea must be of lowering the threshold with more of scaffolding in the initial levels. Finally, the results show an interesting comparison between educational games and leisure games. Some of the students stated that they were not interested in programming, or games about programming. This was not fun, and to make it fun it should be about something else than programming (Quote 4). Other students expressed that they enjoyed the game, found it fun (for being a learning game), but that they would not want to play this game outside school. “To some degree the game was fun. But I think it was very much the same over and over again. Maybe it should be about something else than programming. For example, about going on an adventure.” **Quote 4**. Student about motivation and enjoyment. Maybe that the challenge is to make programming an enjoyable adventure?

4.3 Comparing and Merging the Results

Both analyses that are presented above have results that can answer the research questions. The themes found in the literature study can be found in the upper part of the left circle in Fig. 2, and the themes found in the game evaluation have been placed in the upper part of the right circle. The intersection of the two circles shows the themes that occurred in both the studies. Combined these themes create a preliminary framework for Girl Inclusive Educational Game Design, with the idea of games with Wide Walls, a High Ceiling and a Low Threshold.

Even if the study by Barlett et al. [58] found that students playing either a violent or non-violent video game increased their cognitive performance, it is an easy choice to go for Exploration Without Violence. To learn by explorations seems clearly better than learning by aggression, and as pointed out by Ferguson et al. [59], stress girls out. To take the violence away is also easy from the game construction aspect, and a good backstory with an exploratory gameplay would be appealing to most boys as well. The second theme Collaborative Interaction is certainly more complex to implement, since collaboration mechanisms would make the game a multi-player game. On the other

hand, multi-player games clearly have a potential to facilitate the identified challenge of learning to program [60].

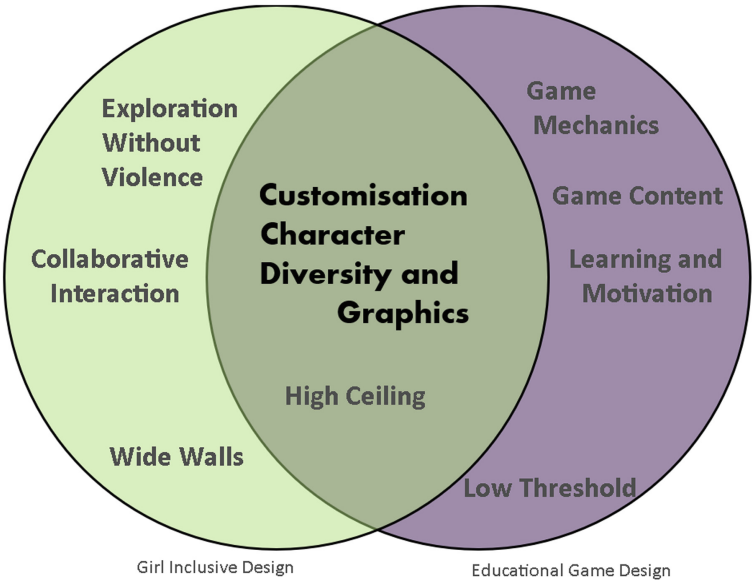

Fig. 2. Girl Inclusive Educational Game Design (Graphics by Peter Mozelius).

Looking at the themes in the intersection set, it would also be a challenging game construction to implement freedom for players to configure the game world exploration, with individual gaming paths. Clearly less complex, and maybe more important to implement, are configuration features for the game characters. As highlighted by Leonhardt & Overå [49], games without inspiring female characters will scare girls off, and as suggested by Spangenberger et al. [50], there are good reasons for having female protagonists in games as well. Looking from the boy perspective, it would for several reason be motivating for them to configure their protagonists, antagonists and heroes. Regarding the theme of Graphics, developers of educational games have it hard to compete with the high-end graphics in commercial-of-the-shelf (COTS) games. For a girl inclusive design, the recommendation could be, as in Osunde, Bacon and Mackinnon [61], to use cartoon graphics and not to dark colour schemes.

Regarding the themes in the upper part of the right circle all three factors are crucial if the result should be an educational game with learning outcomes. If Game Mechanics are to poor, learners would not like to play, and the result could be more of an e-book than a game. Without adequate Game Content the game could be enjoyable to play, but not a good educational game where players learn something. An important concept in many games is the progression of challenge, and to keep players in the flow channel. The term flow channel was defined by Csikszentmihalyi [62], as a state of peaked enjoyment and intense focus, in the continuum between boredom and anxiety.

However, in the case of educational games on programming, the content is increasingly challenging, and the gameplay must not necessarily increase simultaneously. For players without earlier programming and gaming skills, a too high level of challenge could lead away from the flow channel. In the genre of educational games on programming a gentle start, or a low threshold, seems preferably. On the other hand, it is important with a challenging learning progression to keep players in the flow channel both by joyful playing and challenging learning. Flow, and the factor of Learning and Motivation are both depending on a balance between the factors of Game Mechanics and Game Content. With too much focus on content and learning outcomes the game might appear too serious, and less enjoyable. On the other hand, if the content is overshadowed by the gameplay, the result might be gaming only for the sake of gaming, and not gaming for learning.

5 Conclusion

The accumulation of results from two separate studies with separate research questions were merged into the preliminary framework depicted in Fig. 2. A thoughtful consideration of the found factors could lead the idea of a Girl Inclusive Educational Game Design. In this preliminary framework all factors are equally weighted, but the factors found in both studies might be the most neglected ones. To implement customisation in all aspects would be complex, but the identified request for character diversity and creative features for character customisation seems relatively easy to implement. Adding features for customisation could definitely support the ideas of wide walls and a high ceiling in a game.

6 Limitations and Future Research

As noted earlier, the framework for a Girl Inclusive Educational Game Design presented in this study is a preliminary one that builds on previous studies by the authors that have been merged. With that said, more research is needed to determine if the design factors that have been identified in this study encourages girls and boys to play and learn together. This would be an interesting next step of research, developing and evaluating a new and updated game with a more carefully planned out design based in the design factors of this study. Future research should also incorporate a larger group of student testers with different gender and background, preferably in a mixed-methods approach.

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