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Abstract:

As business firms seek a diverse talent pool to attain a competitive advantage, the need for inclusive education has become even more apparent across academic domains. An essential way to impart inclusive education today includes digital tools such as educational games. In this study, we apply the design science research (DSR) Gestalt methodology to develop an inclusive educational game that would advance learning for both male and female engineering students. We also assess the game's efficacy in achieving performance improvements using a survey-based experimental design. Results demonstrate that the game resulted in greater student performance compared to traditional round-table discussions. Additionally, the game had a greater positive impact on female students' performance compared to male students. The study shows that one can apply the DSR Gestalt method to develop gender-inclusive educational games.

Keywords: Inclusive Education, Inclusive Educational Games, Design Science Research, Serious Games, Collaborative Learning, Student Performance

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1 Introduction

Achieving inclusive educational outcomes requires pedagogical tools that can foster high engagement and active learning among all students. Unfortunately, traditional instruction methods such as lectures and discussions cannot adequately actively engage today's diverse student population, which requires more immersive, technology-enabled tools (Cegielski et al., 2011). Therefore, as an industry, education has seen a spurt in investments in using digital tools such as educational games (Wan, 2021). An educational game or gamification refers to an IT artifact or a digital tool that uses game-design elements in any non-game system context to increase users' intrinsic and extrinsic motivation and helps them to process information, better achieve goals, and/or change their behavior (Treiblmaier et al., 2018).

Among their benefits, educational games, as compared to traditional instructional methodologies, can immerse learners and motivate them through playful interaction and regular feedback regarding their progress (Heim & Holt, 2021; Prensky, 2001; Rahimi et al., 2021). Additionally, educational games can present students with realistic problem-solving scenarios and learning opportunities without exposing them to the risks of real-world situations (Hartmann & Gommer, 2021; Westera et al., 2008). Consequently, some have predicted the market for educational games to increase at a compound annual growth rate of 38 percent from 2020 to 2027 and projected investments into the market to reach US$88.11 billion by 2027 from US$9.20 billion in 2019 (Verified Market Research, 2020).

Although pedagogy frequently uses educational games (Shortall et al., 2021), few inclusive educational games exist that are rigorously designed and tested to solve human-centric issues, such as gender differences in learning and motivation, and achieve definitive student outcomes (Forni, 2020). On the contrary, we see a trend toward hurriedly developed and implemented educational games without serious thought about the specific problem the technology intends to solve (Mora et al., 2020). For example, although educational games offer learning advantages, these may not specifically focus on motivating female students (Breslin & Wadhwa, 2014; Rankin & Irsh, 2020), which may cause problems since gender-related cues in the gaming context can induce lower self-efficacy and stereotype threats among women (Behm-Morawiz & Mastro, 2009; Kaye & Pennington, 2016). These gender-related stereotype threats may adversely impact female students' performance and their interest in science, technology, engineering, and mathematics (STEM) fields (Fordham et al., 2020; Shapiro & Williams, 2012).

Prior research has confirmed that female engineering students continue to score lower on learning outcomes compared to males and have a higher dropout rate even though they use educational games that supposedly bridge the gender gap (Bond et al., 2014; Isphording & Qendrai, 2019; López-Iñesta et al., 2020). Given that females can perform at equal or even better levels than their male counterparts, these adverse outcomes for female students most likely result from poor gaming designs that reinforce negative gender stereotypes and fail to counter the other cultural and environmental factors that magnify such stereotypes.

As many studies on this topic indicate, these limitations have drawn researchers to focus on designing and developing inclusive educational games that can benefit diverse student groups (including females) (Hanghøj et al., 2018; Rankin & Irish, 2020; Shliakhovchuk, 2018). However, despite these valuable research initiatives, designing an inclusive educational game presents many challenges, and research related to developing and testing such educational games remains limited. With this study, we fill that gap by developing and testing an inclusive educational game to improve first year students' (especially females) performance in an engineering program.

Developing an inclusive game requires the use of relevant theoretical framework to drive the design and methodology to design and evaluate IT artifacts (Gregor & Hevner, 2011; March & Storey, 2008). For example, researchers have applied DSR methodology to develop a network-based customer service system (Brohman et al., 2009) and a prototype Web application that supports cultural adaptability (Reinecke & Bernstein, 2013). These and other past studies indicate that the DSR might provide a sound theoretical foundation for designing an inclusive, human-centric educational game as well (Adam et al., 2021; Prinz et al., 2021). With its focus on experimentation, piloting, observation, learning, and development, the DSR methodology can help designers develop educational games to meet the needs of the marginalized student population. The DSR gestalt method in particular focuses on synergistically improving human behavior and IT system designs with evaluation evidence drawn from multi-criteria human/technology studies (Adam et al., 2021). Therefore, we applied the DSR gestalt method to develop an inclusive educational game using a reiterative refining and redesigning process based on user and evaluator feedback. Accordingly, we addressed the following research question (RQ):

RQ1: How can one apply the DSR gestalt method to develop an inclusive educational game for engineering students?

When developing an inclusive educational game, one needs to evaluate its impact on student outcomes (Mayer et al., 2014 to ensure that the game has the intended impact on the vulnerable group. We assessed the game's efficacy in improving student performance in general and female student performance in particular (Mayer et al., 2014). As prior researchers have recommended, we evaluated the game both qualitatively and quantitatively (e.g., Abdellatif et al., 2018). We obtained qualitative data from subject-matter experts, an evaluation team, and student focus groups regarding user experiences and perceptions of game design features. We used quantitative data to assess serious game's efficacy in improving student performance compared to a traditional instructional method (namely, round-table discussion). Accordingly, we addressed the following two research questions:

RQ2a: Do first-year engineering students perform better when learning via an educational game compared to round-table discussions?

RQ2b: Do first-year female engineering students perform better when learning via an educational game compared to round-table discussions?

We structure the paper as follows: in Section 2, we review the literature. In Section 3, we discuss the methodology we followed to conduct the study. In Sections 4 to 8, we discuss our findings and discussion, implications for research and practice, contributions, limitations, and conclusion.

2 Literature Review

2.1 Need for Inclusive Education and Inclusive Educational Tools

As business firms operate globally, cultural, social, and ethnic diversity compound the challenges they face (Fatehi & Choi, 2019). Concurrently, educating a diverse student pool to create a talent pool that can address these challenges has become critical. Thus, in recent years, we have seen a tremendous push toward diversity and inclusion in both academia and the corporate world (Farndale et al., 2015; Fuentes et al., 2021). Whereas diversity efforts relate to increasing minority and female representation, inclusion involves ensuring equity, mutual respect, and active participation of underrepresented groups in decision making (Mehta et al., 2021). Promoting diversity and inclusion requires one to develop inclusive educational policies, systems, and tools (Meskhi et al., 2019; Mitler, 2000).

Inclusion in the education context refers to a process that involves identifying and removing barriers to learning and ensuring all students (especially marginalized groups) can participate and achieve their learning goals (Ainskow, 2005; Nieminen, 2022). Thus, inclusive education provides equal learning opportunities to diverse stakeholders irrespective of their race, gender, age, and ethnicity and ensures that all students have an equal chance to participate, learn, and achieve without any adverse impact. Inclusive education plays an instrumental role in creating a diverse talent pipeline that can fulfill the corporate world's recruitment demands. As firms shift from reactive to proactive recruiting based on diverse talent pools and pipelines, the role that academic institutions play in creating that pipeline is becoming critical. Consequently, calls for inclusive education have also intensified (Ray et al., 2018; Westin et al., 2019).

The need for inclusive education necessitates the use of inclusive educational tools. Educational tools refer to the various software programs, technologies, and content used in pedagogy for instruction, such as simulations, video games, case studies, and Web-based instruction. These educational tools' design features can create barriers to learning for vulnerable student populations such as females (Orser et al., 2019). Alternatively, an inclusive educational tool can narrow this learning gap. In a study examining gender inclusiveness in educational technology, Heemskerk et al. (2009) concluded that:

> *Gender scripts are embedded in educational tools, which are reinforced in classroom practice and affect learner experiences. Greater inclusiveness of the tools appears to improve the participation of students, enhance positive attitudes toward learning and technology, and improve the learning effects as reported by girls and boys. Girls especially tend to benefit from the inclusiveness of educational tools* (p. 253).

Other studies also attest to the need for and benefits of inclusive educational tools such as games for improving the learning of all students (e.g., Akinrinola et al., 2020; Heemskerk et al., 2009; Jaramillo-Alcázar et al., 2020; Stone et al., 2019). Thus, the use of digital games has seen a significant increase lately in all aspects of life (Schwartz, 2021). However, in this study, we pay specific attention to the increasing interest games have received from educators (Minaie et al., 2021; Papastergiou, 2009; Putz et al., 2020).

Prior research shows that educators have used some educational games to impart inclusive education (Akopyan et al., 2019; Budnyk & Kotyk, 2020). Based on Mehta et al. (2021) and Ainskow (2005), we define an inclusive educational game as a pedagogical information system that minimizes barriers to learning and ensures all students can equally participate and learn. For example, an inclusive game should be equally effective in improving both male and female students' learning and performance. One must design and assess such a system for its impact on different student groups before implementing it. Prior researchers in healthcare and social work have discussed inclusive healthcare and social network-based games (Eftring, 2011; Pourabbas et al., 2017). In the educational domain, research on designing games for different student cohorts has made this new research area an exciting one (e.g., Anderson et al., 2017; Metatla & Cullen, 2018; Roland & Yalcin, 2020). However, designing and implementing inclusive educational games in higher education remains limited and the DSR method might be apt for these processes (Adam et al., 2021; Cotán et al., 2021).

2.2 Design Science Research Gestalt Method

DSR constitutes a valuable approach to designing educational games since it specifically focuses on "ill-structured" or wicked problems and "seeks to explore new solutions to solve problems" (Adam et al., 2021; Holmström et al., 2009, p. 67; Romme & Dimov, 2021). Additionally, the methodology allows for artifact experimentation, prototyping, refining, and testing as part of the customer-focused process (Brown, 2009; Griesbach, 2010; Prinz et al., 2021). Design thinking allows for flexibility, multiple perspectives, and integrative thinking in creating unique solutions (Baskerville et al., 2011; Diederich, et al., 2021; Johannesson & Perjons, 2021; Michlewiski, 2010).

Adam et al. (2021) propose a DSR gestalt method for integrating both the interior and exterior modes in human-computer interaction (HCI) research. In the interior mode, researchers focus on technically designing IT systems and their interfaces to enhance human performance and solve complex problems. In the exterior mode, researchers derive new design knowledge from observing and analyzing existing IT systems in the real world outside their original development environments. Integrating the interior and exterior modes using the DSR gestalt method would focus on synergistically improving human behavior and IT system designs to enhance human performance. Iterative interior and exterior research activity cycles would continually refine the IT system interfaces and the human interaction artifacts.

This ability to continually refine artifacts during the development process based on user and design experts' inputs represents one of the DSR method's key strengths. The inherent experimentation and reiterative loops allow one to develop an inclusive game with rich design features. Potential weaknesses include the time, money, and effort it takes to develop an effective artifact and the need for diverse feedback to develop an inclusive game fit for diverse stakeholders. However, despite such constraints, DSR provides a solid foundation to develop inclusive digital games.

We found several examples of researchers examining the DSR methodology to design educational games. Le Compte (2021) used a DSR approach to investigate serious games for cybersecurity-related purposes (Awojana et al., 2018). Khaleghi et al. (2021) used the DSR approach to provide a framework for gamifying cognitive assessment and training by synthesizing current gamification design frameworks, existing research, and input from field experts. Engström and Backlund (2021) discussed how one can frame serious game development as a process that combines gameplay experience (e.g., enjoyment and engagement) with goal achievement (e.g., learning and problem solving) using DSR.

Thus, extending prior research, in this study, we applied the DSR gestalt approach to design an inclusive educational game to teach students about engineering design. Figure 1 presents our research model based on DSR and the theory-based framework for gamification research that Treiblmaier et al. (2018) proposed. The left side of the model explains the three phases in game development using the DSR gestalt method (RQ1) and the right side presents the relationships that we tested to evaluate the game's impact on first-year engineering students' performance (RQ2a and RQ2b).

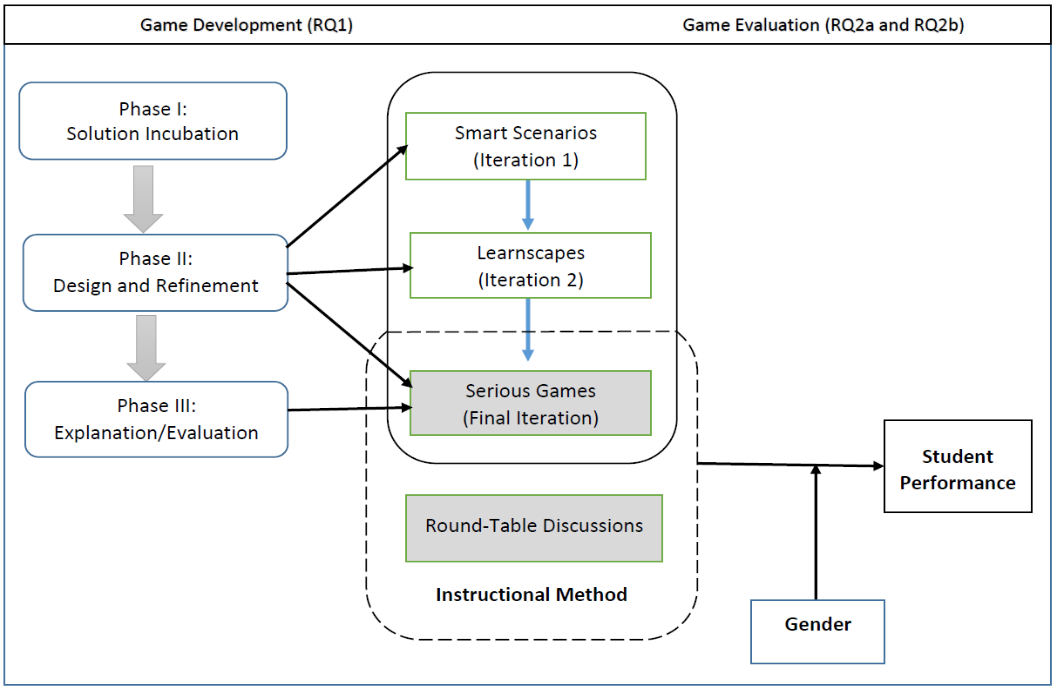

Figure 1. Research Model (Drawn from Adam et al., 2021; Treiblmaier et al., 2018)

3 Research Methodology

In collaboration with a private company, the second and third author and another professor (not an author in this study) from the engineering college of a Southeastern university in the United States developed three iterations of an inclusive educational game in a laboratory over a two-year period. Prior research recommends two methods to achieve gender inclusiveness in software: 1) using inclusive design methods and processes and 2) improving software's fit to different genders through design features (Lucke & Castro, 2016; Vorvoreanu et al., 2019; Williams, 2014). For example, research recommends involving women in game design decision-making processes (Vorvoreanu et al., 2019; Williams, 2014), ensuring diverse game development teams (Westin et al., 2019), and seeking feedback from diverse subjects in the developmental phases (Rankin & Irish, 2020). Also, games should have human-computer interaction (HCI) features such as rewards and customized feedback to promote inclusion.

In this study, the design team for the game comprised two males and two females, while the development team comprised two males and three females employed by the company. The external evaluation team for the game comprised two female professors from the education department in another university. The evaluation team evaluated the game in each iteration and provided feedback to the development team. Thus, females actively participated in all design, development, and evaluation stages for the game. The design team, which a female led, adopted several HCI features in developing the game to make it inclusive based on design and development team members' insights and the evaluation team's feedback. The evaluation team reported that female students responded enthusiastically to using the game to learn about engineering design and suggested the game adopt a gender-neutral design. Also, feedback from focus groups and experts prompted the design and development team to make the game more interactive, flexible, and easy to navigate. The design and development team also designed the game such that the students could work at their own pace in a fun environment and receive immediate feedback. These features, as confirmed by prior research and the qualitative and quantitative data we gathered from the students, indicated the game's inclusive nature. Table 1 presents the HCI features incorporated in the game for inclusion.

The professors worked closely with a company that designs commercial instructional materials and develops educational games. This strategy follows advice from Wyatt and Piggott (2019) who argue that the partnership between academia and industry can develop future talent and upskill current practitioners and, thus, successfully meet the challenges involved in designing emerging technologies. The professors conceptualized the game in the laboratory. The company's technical members then developed a product based on the conceptualization after which the evaluation team evaluated the developed game. Table 2 lists project members' role and gender at the company and the university.

Table 1. HCI Features Incorporate in the Serious Game to Make it Inclusive

HCI feature for inclusion	Reference paper	How the game incorporated the feature
Motion cues	Gauthier et al. (2022)	The game used narration and highlights to guide users through it.
Rewards/ Penalties	Gauthier et al. (2022)	The game awarded points when users succeeded in building a structure and withheld them when they failed to do so.
Points	Saleem et al. (2021)	The game awarded more points to users based on the structures they built, the structures' quality and load capacity, and the materials used.
Progressively challenging levels	Saleem et al. (2021); Steiner et al. (2009)	The game featured three levels—1) a basic tower, 2) a water tower, and 3) a bridge strong enough to support a train—that progressed in difficulty.
Challenges	Saleem et al. (2021)	The game constrained users in various ways, such as overall weight, material cost, and load to make it challenging.
Clear, immediate feedback and instructions for each level	Steiner et al. (2009)	The game provided users with immediate and detailed feedback on their performance. The feedback included rewards, points earned, and detailed explanations. The game provided clear instructions for each progressive level.
Self-pace	Ibrahim et al. (2010)	The users could play at their own pace and read instructions and reflect on feedback they received.
Gender-neutral and inclusive interfaces	Vorvoreanu et al. (2019)	The game used gender-neutral and inclusive interfaces. For example, the game used both male and female avatars for the interactive interfaces.

Table 2. Number of People Working on Project

	Company		University	
Role	**Male**	**Female**	**Male**	**Female**
Leadership	2	-	2	-
Game developers	2	3	-	-
Game designers	-	-	2	2
External evaluators	-	-	-	2

We chose the two evaluators based on their expertise in mixed-methods research, which involves collecting and analyzing both quantitative and qualitative data in a study. In this study, following the concurrent triangulation mixed-methods approach, we collected both qualitative (comments) and quantitative (performance scores on an engineering design task assignment) data from students and subject matter experts and integrated these two data types concurrently (Creswell & Clark, 2011). While qualitative research benefited the effort to develop the game in the first study phase through its open-ended inquiry, quantitative analyses helped efforts to examine whether the game performed as intended in the second phase. Together, the data provided ideas for subsequent game alterations (game development) and testing their impact in the classroom (game evaluation).

The evaluators used focus groups to assess the suitability of developing the game into full-fledged production systems. Each focus group included about 10-20 students, whom we asked to provide feedback about the game in approximately 30-minutes sessions. The evaluators used a structured questionnaire to seek student feedback and prepared a written report. The evaluators implemented each game iteration in a course section and asked students to provide feedback via an open-ended survey or interview questions on the perceived value and nature of the educational game and to judge its strengths and areas that needed improvement. To analyze qualitative data, the evaluators used the thematic analysis approach (Braun & Clarke, 2006) and frequency counts. Braun and Clarke (2006) define thematic analysis as a method for identifying, analyzing, and reporting patterns (themes) in a dataset. Based on the analysis, the evaluation team advised the project team on whether the game met the objectives.

Once the evaluators reported that a game met the necessary objectives, the project team implemented it in several course sections over three semesters in an experimental/control mode and used quantitative evaluations to triangulate qualitative results. The sample for the study comprised first-year engineering students in a mechanical engineering program at a university in the Southeastern United States. They took an “Introduction to Engineering” course that integrated the game. The project team chose this course as all students enrolled in the engineering curriculum need to complete it.

3.1 Developing an Inclusive Educational Game (Addressing RQ1)

We used the DSR gestalt method (Adam et al., 2021) to develop and evaluate an inclusive educational game. The company and the university teams designed the game together. The co-designing process involved the company team working on the interior mode (i.e., technically designing the games and their interfaces to teach the engineering design process) and the university team working on the exterior mode (i.e., evaluating the game in classes, using feedback to improve the design process, and communicating it to the company team). The all-female external evaluation team worked on the exterior mode and evaluated the feedback from the students. Using the DSR gestalt method, these three teams worked together to create a final serious game that would improve students’ performance.

Figure 2 shows the three design phases in developing the game: solution incubation, solution refinement, and explanation. These phases correspond to the steps in the DSR gestalt. Next, we describe how we applied the DSR steps to develop and evaluate an inclusive game.

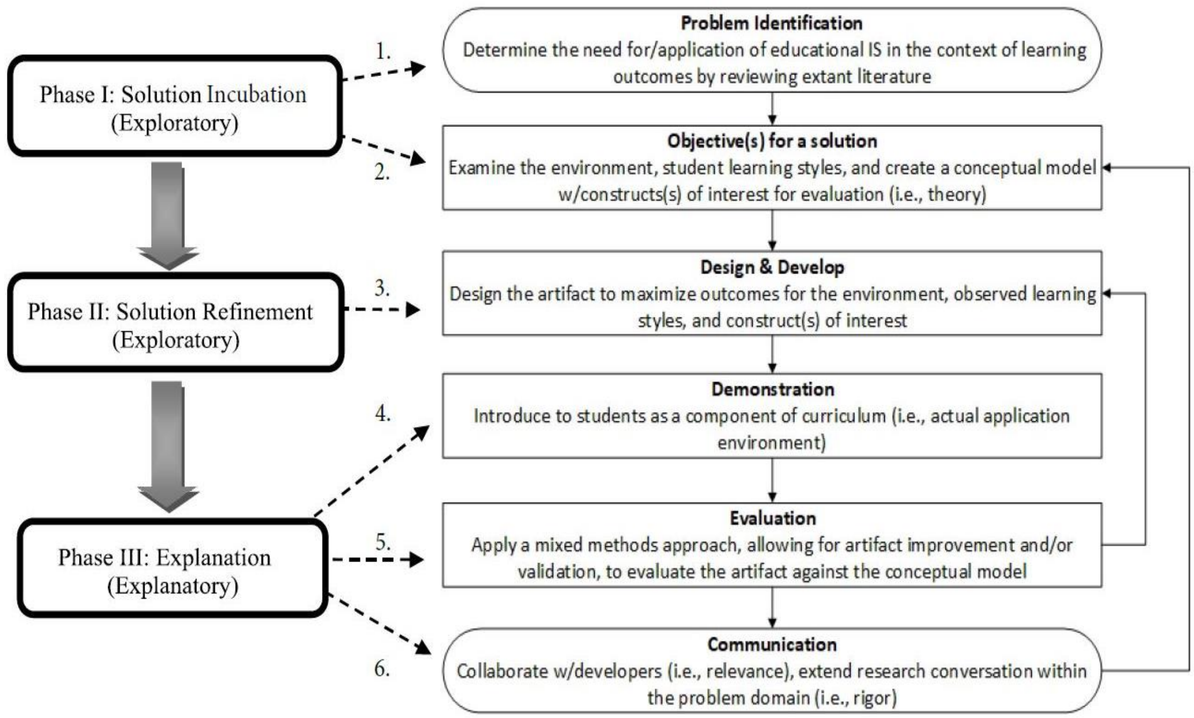

Figure 2. DSR Gestalt Method Used to Design an Educational Game

3.1.1 Steps One and Two of the DSR Method (Problem Identification and Objectives)

Recognizing and defining the problem and developing a conceptual model to solve the problem constitute the first two steps in the DSR method. These steps involve solution incubation whereby one carefully frames the problem and the proposed model for the solution by seeking user and expert inputs and examining the knowledge base across disciplines. In this study, we identified the need for an inclusive educational game for first-year engineering students by reviewing the literature, interviewing current designers, and interacting with individuals who used existing systems. We defined the problem as improving both male and female students' design skills by designing and implementing an inclusive educational game that can accommodate gender differences. We chose engineering design as the topic for the game since it is the core of all engineering disciplines and engineering practice. Engineering experts consider design synonymous with engineering (Mukhandmath et al., 2019) and integral to implementing STEM education (Lin et al., 2021). Calls for improving engineering design skills also drove this development (Burns & White, 2021; Forcael et al., 2021). Following these two stages, the project team designed and developed educational games and evaluated them. Based on the DSR gestalt methodology, the team abandoned a game iteration that did not meet the learning outcomes, and began work on a new one. Table 3 summarizes the process as the teams iterated through different versions.

3.1.2 Step Three of the DSR Method (Design and Develop)

The third step entails actual designing and development of the artifact, which includes determining its desired functionality and then creating it. At this stage, designers apply the information gathered about students and environmental characteristics (e.g., gender differences and learning environment) to design an artifact. During this stage, we developed three game iterations (called Smart Scenarios, Learnscapes, and Serious Game). Table 3 presents the details of the process we followed to develop these iterations.

We had to discard the first two game iterations due to the largely negative feedback from focus groups and evaluating team's reports that they did not meet the learning objectives. The company and university teams had functioned independently for the first iteration. For the second iteration, the design team from the university and the development team from the company worked collaboratively using twice-a-week teleconferences and exchanging notes continually using a file-sharing system. However, the pilot test still revealed substantial issues with the game.

For the third iteration, the company changed the development team and hired experienced developers. The laboratory also allocated two students to work full-time with the company's developers. We divided the project team into several smaller groups, including the external evaluation team, the project leaders (from both the laboratory and company), and the design team (from both the laboratory and company). Team members collaborated and shared updates to the game via email and the file-sharing system. They adopted a rapid prototyping approach that developed the game in nine months.

After developing this third iteration, which we called Smart Game, the evaluation team tested it with a group of 20 students. Most of the students perceived the game favorably. The students enjoyed playing this game and the evaluators recommended its implementation in the Introduction to Engineering course.

3.1.3 Steps Four, Five, and Six of the DSR Method (Demonstrate, Evaluate, and Communicate)

The last three steps in the DSR gestalt methods involve implementing and evaluating the artifact and communicating the results to relevant stakeholders. According to Peffers et al. (2007), experimentation in an actual classroom setting may allow for the most rigorous evaluation methods and the most conclusive feedback. One also needs to communicate the research to both corporate and academic audiences to avoid duplicated effort in developing IT artifacts.

In this study, we quantitatively evaluated the final game version (i.e., Serious Game) with students enrolled in an Introduction to Engineering course over three semesters via an experimental design. The experimental group played the game while the control group participated in round-table discussions to learn about the engineering concept. We compared the male versus female participants' performance on an engineering design task for both groups. We calculated students' performance scores based on how well they did on the assigned task. We also collected qualitative data from the students about the game.

The Serious Game initially presented users with learning objectives and the need to learn about the engineering design process. Next, the game showed poor engineering design examples such as failed bridges from real-world scenarios. The game then provided an introduction and walkthrough that explained how to use the game controls and screen areas. Finally, students progressed to the game's main portion where they encountered three challenges that increased in difficulty.

At the first level, students had to design a tower given specific weight, cost, and load constraints. At the second level, students had to build a water tower that could hold a minimum load. If they did well, the water tower withstood the pressure of water; otherwise, it buckled and fell apart. The final level required students to build a train bridge across a canyon that could hold a minimum load (e.g., a moving train). If they created a good design, the train passed through the bridge; otherwise, it derailed. Students had the flexibility to change the design elements until they achieved a satisfactory solution. The game constrained users only in how much time they had to complete a level. The game gave a score to students after they completed all levels depending on how well they performed. Table 3 provides details about the game-development phases using the DSR method.

Table 3. The Developmental Phases of the Game Using the DSR Gestalt Method

Phase 1: Problem identification and objectives	We determined the need for an inclusive educational game based on: 1) a literature review, 2) results from past studies conducted in the laboratory, and 3) inputs from game designers and game users. We set the solution objective as inclusive learning outcomes for all students.			
Phase II: Design and development	The game-development process involved three game-development iterations based on feedback gathered after each iteration and improvements to accommodate the feedback.			
	What	**How**	**Implementation and evaluation**	**Feedback**
Game iteration 1: Smart Scenario	The design team built a smart scenario from a multi-media case study that academics developed and smart scenarios that their company used. Students took on the role of new employees at a fictional firm where they received guidance through learning activities and an evaluation.	Although the laboratory team (content experts in communications and design),and the company design team (developers and project managers) held teleconferences, the teams mostly functioned independently.	The professors implemented the smart scenarios in multiple sections in the introductory engineering course. The evaluation team gathered qualitative feedback from student focus groups.	The focus groups responded largely negatively to the game. Suggestions from the focus groups included shortening the script, changing the navigation (e.g., more opportunities for interaction, making it more like a game, and adding scores).
Game iteration 2: Learnscapes	Based on evaluating the smart scenarios, the design and development team created Learnscapes using a template the company already used in high schools and for-profit universities.	Each team met twice a week or had teleconferences with project managers to advance the storyline and specific learning objectives for their Learnscapes. The design process involved collaboration among three teams of content experts from the laboratory, one for each Learnscapes, and discussions with the company regarding product design.	The evaluation team tested the game prototype with 15 students seven months into the project. Following the pilot test, the evaluation team conducted an assessment via a focus group.	The focus group made both positive and negative comments. Meeting minutes following this pilot test stated that the "pilot test did not go so well". The feedback showed that technical problems seriously detracted from the game's focus and flow, that users could not control outcomes, and that it felt more like a tutorial. Issues with content accuracy arose as well.

Table 3. The Developmental Phases of the Game Using the DSR Gestalt Method

Game iteration 3: Serious Game	Based on feedback, the design team built a design game called *Smart Game* from scratch based on students' and the evaluation teams' feedback. The game presented failed bridge examples that resulted from poor design, an introduction, a tutorial on how to use the controls and screen areas, and three gaming levels.	The laboratory and the company held teleconferences and face-to-face meetings. The design team had members from both the laboratory and the company. Members shared updates via email and a file-sharing system. Following feedback on the prototype, the designing and evaluation teams collaborated on the final version.	The evaluation team tested a prototype of the game with 20 students to provide qualitative data for the final version.	Among the 20 students in the focus group, 17 reported a positive experience. Also, the design team noted several minor bugs and navigational details. Common positive themes included fun, game-like, kept my interest. Common areas that needed improvement included need for better feedback, no specific learning objective, and the need precise calculations.
Phase III: demonstrate, evaluate, and communicate	We quantitatively evaluated Serious Game with 238 students enrolled in an Introduction to Engineering course over three semesters via an experimental design. The experimental group played the game while the control group participated in round-table discussions. We compared male versus female participants' performance for both groups.			

3.2 Evaluating Serious Game (Addressing RQ2a and RQ2b)

3.2.1 Experimental Design and Sample

The project team chose an Introduction to Engineering course to acquire the sample because all engineering majors need to complete it. The study sample involved 238 and primarily Caucasian (206) students (198 males and 40 females). We divided the sample into experimental (142) and control (96) groups in multiple sections of the introductory course over three semesters. The students in the experimental groups worked with Serious Game, while the students in the control groups participated in round-table discussions. The round-table discussions involved problem-based learning with students working in groups to generate discussion in the form of writing, verbal communication, and analytical thinking.

We chose the round-table discussion as a representative traditional instructional method since it involves participants and constitutes a well-established pedagogy (Lewis-Kipkulei et al., 2021). A round-table discussion engages students in ways that help them integrate new and interesting content knowledge with prior knowledge through a structured debate format. Throughout the entire preparation process, students read relevant text, research subtopics, and prepare written notes. This research then allows them to engage in active discussions with their peers to arrive at a consensus regarding the assigned topic (Model Teaching, 2021).

To test if students' learning improved from using the educational game or the round-table discussion, the instructors asked the students to build a tower as tall and strong as possible with the materials provided (i.e., a box of pasta, a roll of masking tape) within two hours. Each team planned and designed, built, and tested a tower by placing increasing weights on the structure until it collapsed. The game recorded these weights and we used the following formula to calculate each tower's performance:

$$\textit{Pasta tower performance factor} = \textit{tower height}^2 \times (\textit{weight of supplies/tower weight}) \times \textit{load supported by the tower} \quad (1)$$

The group that designed and built a tower with the highest performance factor received bonus points.

Because the pasta tower required students to design a tower and receive a performance score, the evaluation team determined that it could serve as a proxy for learning. Scores from the pasta tower allowed evaluators to compare how well students in the control group understood the engineering design process compared to students in the experimental group. Table 4 shows the details of the teaching and evaluation schedule followed each semester.

Table 4. Experiment Schedule

Week	Lecture (one hour)	Experimental lab (three hours)	Control lab (three hours)	Evaluation during lab
11	The instructor taught engineering design concepts	Students played Serious Game	Students participated in round-table discussion	Students completed a survey
12		Students worked in teams to build a pasta tower as high as possible	Students worked in teams to build a pasta tower as high as possible	We evaluated each pasta tower and computed the pasta tower performance score for each group
13				Focus groups for control and experimental groups.

3.2.2 Reliability and Validity

To ensure study validity and reliability, we collected data from at least two sources for each DSR step and multiple sources for the overall process as prior research recommends (Moon, 2019). We also generated quantifiable measures, such as how much design team members communicated with one another via meeting minutes and email exchanges. The major data-collection sources included prior literature, National Science Foundation (NSF) proposals, emails, meeting minutes, survey responses, focus group responses, input from previous game iterations, instructor reports, students' grades, faculty-company partner meetings, and Serious Game scores.

3.2.3 Quantitative Results

We show the mean scores that male and female participants achieved in the experimental and control groups in Table 5. We performed independent sample t-tests to determine whether the mean scores for the two groups showed a significant difference. Additionally, we measured the effect sizes using Cohen's *d* (Cohen, 1977) to see how much the groups differed. In interpreting, Cohen's *d*, 0.8 represents a large effect, 0.5 a medium one, and 0.2 a small effect size. We found no difference between the male and female students' pasta tower scores in the experimental group (i.e., Serious Game) (see Table 5), which evidences Serious Game's inclusive nature. In comparison, male students did significantly better than female students in the control group (round-table discussions) with a large effect size (0.81).

Table 5. Comparison of Male and Female Students' Performance within the Experiment and Control Group Instruction Method

	Mean	Standard deviation	Study sample (n)	T statistic	Degrees of freedom	P-value	Cohen's *d*
Serious Game				0.724	132	0.470	0.164
Males	5073.84	3869.11	109				
Females	5686.31	3552.22	25				
Round-table discussions				3.169	87	0.002	.81
Males	4155.84	2682.13	75				
Females	2264.74	1908.36	14				

The independent samples t-test for the experimental and control groups showed a significant difference in the pasta tower scores between the groups with the students enrolled in Serious Game sections scoring higher on the pasta tower exercise than the students in the round-table discussion sections ($p < 0.01$) (Table 6). As such, the students who learned with Serious Game performed better than students who used round-table discussions with a medium effect size (0.40).

Table 6. Comparison of Overall Student Performance in Experimental and Control Group

Variable	Mean	Standard deviation	Study sample (n)	T statistic	Degrees of freedom (df)	P-value	Cohen's d
Pasta tower score				-3.071	221	0.002	0.405
Serious games	5188.11	3806.63	134				
Round-table discussion	3858.37	2658.35	89				

Further examination revealed that we could attribute this difference mostly to the females in the Serious Game section. We assigned female students to work with male students in both experimental and control groups. However, when comparing female students' scores between control and experimental groups, females in the experimental group scored noticeably higher on the pasta exercise than their peers in the control group ($p < 0.01$) (see Table 7). Also, female students who participated in Serious Game performed better than the male students, whereas female students who participated in the round-table discussions performed worse than the male students in the control group.

Table 7. Comparison of Male and Female Students' Performance across Instructional Methods

Variable	Mean	Standard deviation	Study sample (n)	T-statistic	Degrees of freedom (df)	P-value	Cohen's d
Males				-1.901	182	0.059	0.275
Serious Game	5073.84	3869.11	109				
Round-table discussion	4155.84	2682.13	75				
Females				-3.332	37	0.002	1.19
Serious games	5686.31	3552.22	25				
Round-table discussion	2264.74	1908.36	14				

We then applied hierarchical multiple regression to examine the main effects and interaction effect of gender and instructional methodology (Serious Game vs. round-table discussions) on the pasta tower scores. We show the results in Table 8. As Table 8 shows, we found a significant interaction effect between gender and instruction ($p < 0.05$). Specifically, female students performed significantly better than the male students with Serious Game as the instruction method.

Table 8. Regression Results for Gender and Instructional Methodology

Variable	ΔR2	Standardized beta (β)
Step 1		
Gender		0.034*
Instruction		0.190**
ΔR2 after step 1	0.037**	
Step 2		
Gender X Instruction		-0.363*
ΔR2 after step 2	0.018*	
Overall ^{R2}	0.055	
Adjusted R^2	0.042	
Note: all tests are two-tailed. The overall method for the regression was significant ($F(3, 219) = 4.217$, $p < 0.05$). *p < 0.05, **p < 0.01, ***p < 0.001. ΔR2 = change in R2		

3.2.4 Qualitative Results

Researchers have underscored the important role that qualitative insights play in the evaluation process (Moizer et al., 2019). Researchers have also recommended several criteria to assess serious games (see Abdellatif et al., 2018; Dele-Ajayi et al., 2016; Girard et al., 2013; Zhang et al., 2013). Therefore, we also gathered qualitative data from student focus groups on some of the criteria. Students in both the Serious Game and the round-table sections had positive feedback about their experiences in their respective modules. However, many students in the Serious Game sections commented on the relevance of the content in the Serious Game for developing their pasta tower. Multiple students mentioned that it provided an opportunity for “trial and error”. Comments also indicated that the serious game was received positively and students believed that it promoted learning. Common themes included “it was fun”, “more engaging than a textbook”, “a natural way of learning”, “the format was better than lectures”, “the navigation was easy to figure out”, and “it was an overall positive experience”.

4 Findings and Discussion

We applied the DSR gestalt research method to develop an inclusive educational game for first-year engineering students (RQ1), which we then tested for its impact on student learning (RQ2a and RQ2b). As Table 5 shows, we found no significant difference between male and female scores in the experimental group that used Serious Game, which confirms the game’s inclusive nature. In fact, females had a higher overall mean score in this group compared to males. In comparison, in the control group that used round-table discussions, females performed significantly worse than males, which signals the inequitable impact that the traditional method has on female students’ performance. The game also had a positive impact on student performance overall.

Several characteristics of the process became apparent during game development. Most notably, the teams engaged in more communication throughout the three game-development phases. The DSR method is a build-and-evaluate process based on communicating evaluation results to designers to enable them to improvise. Here, both the quality and the speed of the iterations improved as the projects progressed largely due to the increased communication between evaluators and designers, which ultimately resulted in a better end product. The design process also benefited from subgroups working on specific tasks and reporting back to the overall group and from regular feedback loops incorporated into the design. We also found that a successful product requires close collaborations among the design and development teams.

The design process also highlights the need for rigorous evaluation in developing educational games. The developer team was not used to thoroughly evaluating a game in a classroom setting and had to change the product development platform. Similarly, the academic team was not used to the challenges involved in the production process and had to adjust their pace and expectations. Adam et al. (2021) and Hevner et al. (2004) explain that the evaluation process in DSR sets it apart from design, and our results support this conclusion. The DSR gestalt method encouraged us to use a mixed-methods approach in evaluation, which helped us develop an inclusive game to improve student learning. Interestingly, we found some evaluation instruments to be redundant and removed them from the evaluation process in the project’s final year. For example, we initially measured learning style with a questionnaire but, because it proved insignificant to performance, we dropped it. Also, we dropped questionnaires on perceived improvement in higher-order cognitive skills primarily because the external evaluators received feedback about the project team implementing too many questionnaires.

When considering the impact that Serious Game had on students’ performance, we observed a noticeable difference between the control and experimental groups. As Table 6 shows, the quantitative results show that, overall, all students who used Serious Game scored higher on the outcome criteria than their counterparts who participated in the round-table discussions (RQ2a). More importantly, females scored significantly higher when using Serious Game compared to round-table discussions (RQ2b) (Table 7). On the contrary, female students in the round-table discussion groups performed significantly worse than their male peers in the control group. Thus, we found the interaction between gender and instruction method to be significant (Table 8).

The qualitative data analysis provides further insights into the game’s impact and benefits for male and female students. Students mentioned the game as being realistic, enjoyable, and as providing a natural way to learn. Students seemed to prefer games to other methods such as lectures or textbook reading. They also perceived the game as interactive, self-paced, and fun and that it provided quick feedback to the users. Additionally, students stated that they enjoyed being able to test their designs without having to fear real-world consequences. These features, incorporated in response to student feedback, made the game attractive to both male and female engineering students, and both groups did well when they used the game for learning. The high representation of women engineers in the game's design and development phase and external evaluation influenced game design choices to make it gender neutral. This finding seems to concur with current research that contends that females' active participation in decision-making roles makes a difference (Mehta et al., 2021; Vorvoreanu et al., 2019; Williams, 2014).

Overall, our findings suggest that Serious Game promoted gender inclusiveness in a way that traditional instruction methods do not. Games can be effective pedagogical tools to improve female students' performance and, in turn, representation in engineering education. Given that we designed the game around engineering students, these results provide strong support for using educational games in engineering courses.

5 Implications for Future Research and Practice

Given this study's exploratory nature, it opens several new avenues for future research. First, in reviewing the existing literature, we found that few researchers have applied DSR in IS education, and that we lack research on using DSR methodologies in designing, developing, and testing inclusive IT artifacts and games. Future researchers can build on this study to develop goal-oriented instructional tools in collaboration with business firms. Doing so can create two benefits. The industry developers and academics could benefit from a rigorous roadmap that we followed in this study by integrating the academic research techniques and industry professionals' technical expertise. Also, further research can validate and/or refine the framework and the results that we present in this study to advance knowledge in the field.

Second, in this study, we focused on developing a gender-inclusive game. Our results demonstrate that gender-inclusive games improve both male and female engineering students' performance. Future researchers can apply the DSR method in a similar way as we did to develop appropriate games for different cultures, ages, and other demographics. Such educational artifacts could assist educators in engaging diverse students and providing inclusive education by improving learning and performance opportunities for all student groups. Given the student population's increasing diversity in the US and across the world, educators need to use inclusive pedagogical tools, such as educational games, especially in domains where females' and minorities' participation and performance have lagged.

Third, this study provides the impetus for efforts to further research and apply DSR in other educational domains. Additional attempts to apply the DSR gestalt method to design new games began shortly after our Serious Game project. These attempts included developing supplemental materials with a smaller scope compared to the game we developed. The supplemental materials are concept tutors designed to focus on a single concept in a discipline, such as the Khan Academy videos (Putri, 2021). Unlike serious games, which can address several concepts and take significant amounts of time to master, a concept tutor is more focused and less arduous. Applying the DSR gestalt method in developing such smaller games could prove worthwhile for both validating and advancing the method. Future research in this area can help explain the difference between designing complex and larger games versus simple and smaller inclusive games and their efficacy for different student groups.

Finally, in this study, we focused only on applying the DSR approach. Previous researchers have proposed and applied several alternative frameworks and methods to design serious games (e.g., Ávila-Pesántez et al., 2017; Carvalho et al., 2015; Moreno-Ger et al., 2008). It would be an excellent avenue for future research to compare these alternative methods with DSR; highlight their strengths, weaknesses, and relevance; and identify the most appropriate design approaches for different learning situations.

For practitioners, differentiation is a successful strategy for gaining competitive advantages (Baron, 2021). The design approach for educational games we propose here can potentially assist commercial entities in their desire to differentiate based on quality and inclusivity. As the market for educational games becomes flooded with products and academic institutions compete for the brightest and most motivated students via offering high quality programs, commercial developers will need to produce desirable educational games that help diverse student populations achieve learning outcomes. Applying DSR gestalt method to develop inclusive educational games can help such businesses in their attempts to meet these new market needs.

6 Limitations

This study has several limitations. The first concerns the study's sample, which included students from engineering only and not from other disciplines such as sciences, psychology, business, and history. As such, our results have limited generalizability as engineering students may already have the technical skills required to use such digital educational tools, which others may lack. Also, in some disciplines such as biology and psychology, females may perform better irrespective of the instruction methods used. One must consider these differences among students when generalizing the results.

A second limitation relates to how we computed the performance score for the pasta tower experiment. The students completed the project as a group and all students working on a single pasta tower received the same score, which does not represent an ideal way to assess individual-level learning and performance since all team members get the same score. One could address this limitation in the future by measuring individual learning and performance along with team-level scores. Fortunately, each group comprised students who shared the same treatment.

Third, when designing the evaluation for each game iteration, we faced limitations due to the number of students who enrolled each semester. As we conducted the evaluation study over three semesters, we found it difficult to keep the same students in each section, and we lost several data points due to non-response or identification errors. Also, we only evaluated the impact that the game had on student performance. We did not evaluate the game's individual elements. These factors may have limited the insights that we can draw from our findings since one cannot possibly know which design features had an effect on performance gains. In extending this study in the future, researchers should also assess serious game aspects such as engagement, playfulness, motivation, and active learning (Ávila-Pesántez et al., 2017).

Fourth, we focused on evaluating only the game's gender inclusivity. To be truly inclusive, educational games should achieve learning goals for students from different races, ethnicities, and cultures. Also, we evaluated the game's efficacy in improving student performance only against the round-table discussions. We did not examine other instructional methods, so we cannot generalize the results to other traditional methods.

Finally, we did not perform any tests to identify differences among the groups. Although all groups had similar social characteristics (e.g., age, gender, race, and so on), they could still differ based on IT skills, attitudes, or abilities. Such differences could impact the results and should be verified before testing the game in future studies. Doing so would further ensure that the performance differences result from the educational tools and not students' characteristics.

7 Contributions

In recent years, we have seen an increased focus on developing and implementing inclusive pedagogical tools that promote learning among diverse students. We contribute to this domain in several ways. First, we demonstrate that one can use the DSR gestalt method to develop inclusive educational games to promote engineering students' learning outcomes. We lack research on applying the DSR gestalt method to develop pedagogical IT artifacts. With a growing emphasis on hands-on, engaging pedagogical tools to prepare students for handling real-world problems, this study shows that educational games designed and developed for specific goals can play a significant role in student learning and performance. We used the DSR gestalt method to develop an inclusive serious game to engage and motivate both male and female students and demonstrated its efficacy by evaluating it in an engineering course.

Second, the results contribute to the literature on inclusive education and DSR methodology. With the growing diversity of the U.S. workforce and customers, companies have concerns about an appropriate talent pool. This demand for a diverse talent pool has necessitated that educational institutions rethink their diversity and inclusion policies and methods. This study constitutes a step in that direction. It provides insights on how to design inclusive IT-based educational games using the DSR gestalt method to bridge the gender gap and encourage female students to perform well in technical and engineering fields. Given females' participation in technical fields represents a challenge, we found significant findings that can trigger future research and practice in the field

Third, our study demonstrates that females' active participation in design decision-making processes and evaluation has positive implications for game development and its impact on female students. The design and development team in our study had more females than men and the external evaluation team comprised two women. The evaluators interpreted qualitative responses from male and female students and shared valuable insights such as making the game more flexible, enjoyable, and feedback oriented. The quantitative results also support the proposition that female engineers' involvement helped in developing an inclusive game that female students received well and that had a positive impact on their performance. These results support and extend previous research that women should have a greater role in decision-making processes (Mehta et al., 2021; Vorvoreanu et al., 2019; Williams, 2014).

Our results align with previous research that proposes that students learn significantly more from inclusive tools than from non-inclusive tools (Heemskerk et al., 2009). We showed that round-table discussions had an inequitable impact on female performance, whereas the game did not. Moreover, all students performed better when using the game compared to the traditional method. The qualitative data analysis also shows that females who used the game reported that they learned more and felt more enthusiastic about what they learned compared to females in the control group. The results validate Kenney et al.'s (2012) decade-old conclusion that women are "different, not deficient" as evident from our significantly different results for female students in the experimental and control groups.

Fourth, we highlight the need for a reiterative process, regular communication, clear feedback loops in designing goal-oriented IT artifacts that meet the needs of a diverse set of students. We needed to go through three iterations before the end product met the design needs and received positive feedback from end users (i.e., the student focus groups). Additionally, it became clear that we could not modify the earlier game versions (i.e., Smart Scenario and the Learnscapes) incrementally to solve the problem. The feedback from focus groups revealed that we had to create a novel and different product to solve the problem with significant cost and time investments from the company and the laboratory.

Finally, this study highlights the need for cross-fertilization between academic research and industrial product development. In doing so, we answer the call of previous researchers to develop active research-production collaborations to broaden the impact of academic research and align game research with game development (Passarelli et al., 2020). In this study, the academic lab applied the DSR theory in conceptualizing a practical pedagogical tool (Serious Game) that would promote inclusive learning. A company then developed the game in close collaboration with academic stakeholders. Both the conceptualization and reiterations based on the DSR methodology and the company's efforts to actually develop the game played a critical role in ensuring a successful outcome. Thus, this study not only shows the need for a stronger nexus between academic and corporate stakeholders in designing such IT artifacts but also that theoretical insights and practical relevance complement each other (Faizi & Umar, 2021; Holmström et al., 2009). Such cross-collaborations also provide an opportunity to integrate the internal and external modes of HCI research and combine the exploratory and explanatory research for an optimum outcome.

8 Conclusion

This paper demonstrates that one can apply the DSR gestalt method to design inclusive educational games. In general, the benefits we identified resulted from 1) significant female representation and participation in designing and developing the game, 2) enhanced planning that involved experts and end users, 3) multiple iterations during the game-development process, 4) rigorous qualitative and quantitative game evaluations, and 5) close collaboration and frequent communication among the design and development teams throughout the project. While these activities required additional time and effort at many project stages, they also reduced the long-term costs and time needed to develop the game and improved the final game's quality. We believe that successfully using the DSR gestalt method to develop inclusive educational games has great potential for improving female students' performance and encouraging minorities and women to pursue and perform well in engineering and technical fields. Better performance in the classroom would lower such students' dropout rate and would, eventually, increase their representation in STEM fields.

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