Teachers as Informants in Participatory Design for Game-Based Learning

Abstract

The current in-situ, descriptive case study demonstrated how we involved in-service teachers as informants in designing an educational game to enhance middle school students' computational thinking through participatory design. Data were collected from eight in-service teachers at middle schools through individual interviews, focus groups, and field notes. The study results indicated that in-service teachers made 82% of contributions to the Learning facet, followed by 14% of the Gameplay facet, at the early stage of conceptualization. Additionally, participants provided insights on intrinsically embedding content in game design processes by offering valuable and relevant pedagogical content knowledge, including knowledge of content and students, knowledge of content and teaching, and knowledge of content and curriculum.

Introduction

Game-based learning (GBL) could be a promising platform to enhance learning in K-12 settings (Boyle et al., 2014; Klopfer et al., 2009; Qian & Clark, 2016; Author, 2022). Nonetheless, the process of designing a high-quality GBL that addresses learning needs and motivates student engagement in K-12 is complex and challenging (Hauge et al., 2020; Khaled & Vasalou, 2014). Although there are no universal approaches to designing and developing GBL effectively, prior research suggests the importance of involving stakeholders in shaping the artefacts (Ismail et al., 2019; Lanezki et al., 2020; Saiger et al., 2023; Scaife et al., 1997; Schreier et al., 2012; Tucker et al., 2019). As Tucker et al. (2019) argued, "Part of the success of game design is participants' willing engagement in creating works of their own choice and vision (p.3)." Consequently, participatory design, which emphasizes stakeholder involvement to enhance the usability and effectiveness of game design, has been attracting more attention in the past decade (Ampatzidou & Gugerell, 2019; De Jans et al., 2017; Ismail et al., 2019; Lanezki et al., 2020; Saiger et al., 2023; Scaife et al., 1997).

The roots of participatory design can be traced to the Scandinavan cooperative design tradition in the 1970s, which highlights the collaborations between labor movements and academia in supporting stakeholder participation in the design of work environments (Bjerknes et al., 1987; Khaled & Vasalou, 2014; Spinuzzi, 2005). In participatory design, stakeholders are invited to cooperatively engage with designers, developers, and researchers at specific stages of an innovation design process, which include the initial exploration of the problem, design solutions, and evaluation of proposed solutions (Hartson & Pyla, 2019; Muller & Kuhn, 1993).

According to the degree to which the stakeholders influence game design, their involvement can be categorized into roles as users, testers, informants, and co-design partners (Druin, 2002). As users or testers, the target group is observed during gameplay and asked to perform usability testing with an early version of the game developed without user input (Druin, 2002). In the informant role, users are asked for input and feedback. As co-designers, users are equal partners in the design process, actively involved and asked for input starting at an early stage, prior to product development (Druin, 2002).

Recent literature reviews, however, report that while participatory design appears to be widely used, it is seldom described or evaluated in detail (Ismail et al., 2019; Saiger et al., 2023; Slattery et al., 2020). Obtaining concrete proof of the value added by participatory design processes is challenging because participatory design's flexible and open-ended nature does not align well with the research methods typically used to measure and quantify outcomes (Ismail et al., 2019; Saiger et al., 2023; Slattery et al., 2020). Research into which participatory design processes are most effective in addressing game design challenges is crucial (Ismail et al., 2019; Saiger et al., 2023; Slattery et al., 2020) because such studies can help identify and expand the range of flexible processes within participatory design, making it more adaptable to various game design contexts.

Consequently, the current case study examines how in-service teachers contribute to the game design process when involved as informants in a participatory design project. The overarching research question addressed is: *What contributions did in-service teachers make when involved as informants in participatory design at the early stage of conceptualization for game design aimed at enhancing middle school students' computational thinking competency?* Specifically, two research questions addressed are: (1) To what degree did in-service teachers contribute to each phase of conceptualization during game design? (2) How did in-service teachers contribute to the learning phase of conceptualization during game design?

Methodology

Research Design

We adopted a descriptive case study approach (Yin, 2009) to explore how in-service teachers, acting as informants, contribute to the process of educational game design. In this study, each participant was considered as a case, used to describe the phenomenon and its real-life context in which it occurred (Yin, 2009).

Participant

We employed a purposeful convenience sampling strategy (Creswell & Poth, 2016) to recruit educators interested in using games for teaching and learning in K-12 settings. We recruited 8 educators from 9 schools (one teacher works at two schools) in 3 districts (see Table 1). Among the participants, 3 were male and 5 were female. The group included 1 instructional coach, 6 middle school teachers, and 1 high school teacher, all specializing in STEM or computer science. Their teaching experience ranged from 3 to 20 years.

Table 1. Demographic information of participants

Name	Gender	Grade	Teaching Year	Position	Subject
PA	Female	Grade 8	20	Teacher, department chair	Mathematics, Engineering, Physics, Science
PB	Female	Grade 8	16	Teacher	Computer science, Mathematics, Technology, Science
PC	Male	Grade 10-12	4	Teacher	Computer science, Mathematics
PD	Female	Grade 7-8	3	Teacher	Science, Technology
PE	Female	Grade 8	4	Teacher	Computer science, Technology, History, English
PF	Male	Grade 6	5	Instructional coach	Mathematics, Technology, Science
PG	Male	Grade 6	12	Teacher	Science
PH	Female	Grade 7-8	5	Teacher	Computer Science, Technology

Data Collection

Data collection consisted of three sources: individual interviews, focus groups, and field notes. We used a structured protocol to guide the 3 individual interviews and semi-structured protocols for the 6 focus groups. Each meeting lasted between 40 minutes and 2.5 hours. A total of 9 meetings were recorded, yielding approximately 450 minutes of video data. All individual interviews and focus groups were transcribed verbatim for analysis. Field notes were taken while the researchers observed participants' interactions and responses during interviews. This data serves as a secondary source to examine the design process from the researchers' perspective.

Data Analyses

We conducted a two-step analysis of the transcripts. In Step 1, based on the expanded Design, Play, and Experience (DPE) framework (Winn, 2009), we developed a coding protocol (see Table 2), highlighting notable patterns of coded narrative and the associations between contexts. The coding set addresses aspects of contributions through four major categories: Learning, Storytelling, Gameplay, and User Experience.

Table 2. The analytic codes used to assess participants' contributions to the four phases of design during participatory game design

Category	Definition
Learning	• Content: The subject matter or knowledge that needs to be learned. • Pedagogy: The methods and practices of teaching, which encompasses the strategies, techniques, and approaches used to facilitate learning and help students understand and retain the content.
Storytelling	• Character: The individuals or entities within the game world that players interact with or control. • Setting: The game world or environment in which the story takes place. • Narrative: The overarching story or plot that unfolds as the player progresses through the game.
Gameplay	Mechanics: Rules, procedures, and systems that govern how players interact with a game.
User Experience	User interface: What the user sees, hears, and interacts with and how that interaction happens

In Step 2, we developed an initial coding scheme based on a Taxonomy of CT in STEM courses (Weintrop et al., 2016) and a practice-based theory of content knowledge for teaching (Ball et al., 2008). This scheme was used to systematically label and index the parts of transcripts categorized under the Learning facet discovered in Step 1. We highlighted notable patterns of coded narrative and the associations between contexts. We noted and labeled the emerging categories and sub-categories, continuously refining the coding as the synthesis proceeded. Concurrently, a cross-case pattern analysis of individual cases was conducted to verify the validity of the coding system (Miles & Huberman, 1994). When consistent patterns were formulated, we identified the categories central to the study. Table 3 displays the final coding scheme used to analyze the dataset.

Table 3. The analytic codes used to assess participants' contributions to the Learning Phase

Category	Definition	Sub-category
Knowledge of Content and Students	Knowledge that combines knowing about students and knowing about subject matter (Ball et al., 2008)	Students' challenges • Data analysis • Data visualization • Conceptual understanding Limited exposure • Complex and ill-structured data • Data collection & creation • Model assessment • Solution preparation • Solution evaluation

Knowledge of Content and Teaching	Knowledge that combines knowing about teaching and knowing about subject matter (Ball et al., 2008)	• CT teaching
		
		• Interdisciplinary teaching
		
		• Performance evaluation
		
		• Engagement and Participation
		  • Collaboration
		  • Competition
		  • Intrinsic motivation

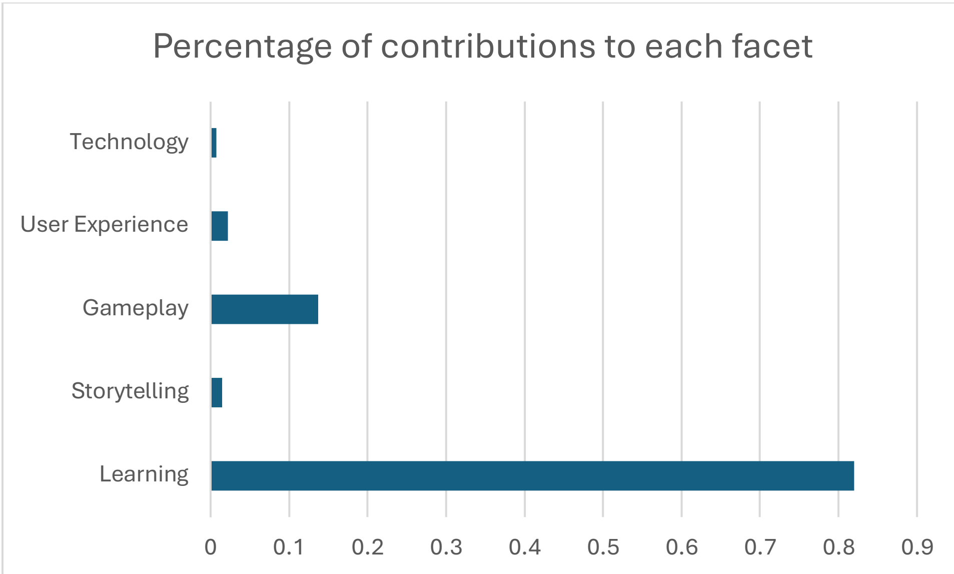
Knowledge of Content and Curriculum	Knowledge that combines knowing about subject matter and curriculum (Ball et al., 2008)	Curriculum focus • Data practices • Computational problem solving • Systems thinking

Findings

Q1

The results from this analysis are presented in Figure 1, which shows the percentage of contributions exhibiting each code we focused on for analysis. We observed the saturation of key dispositions across the sample. Among the contributions the participating teachers made, 82% were for the Learning facet, followed by 14% for the Gameplay facet. The other three facets-User Experience, Storytelling, and Technology-only occupied 4% in total.

Figure 1. Proportion of contributions within the data corpus categorized into four major groups of codes



Q2

The participants made contributions to the Learning Phase by providing pedagogical content knowledge (PCK). We found that when teachers provided information related to PCK, they convey CT concepts, including comparisons, visual aids, examples, clarifications, and practical demonstrations. As such, participants could potentially inspire ways of intrinsically embedding subject matter content into the game design. Several interesting patterns emerged from this analysis.

User-friendly interfaces to visualize data manipulation and increase data collection and creation exposure from a paper-and-pencil approach to digital-based computational tools

The participants discussed the challenges students face when using digital-based computational tools, such as Excel. The examples below illustrate that the lack of exposure and familiarity with these types of tools could be a barrier to students' successful endeavors in data collection, creation and analysis.

> Not all of middle school students from six to eight are tech savvy with all formats except their phones. So unless it's Tik Tok, a lot of them don't know how to use Excel. They don't even know what Excel is. (PE)
>
> I agree. Our kids don't see a lot of sheets. I'm seeing more of it now. (PB)

These discussions indicate that digital-based computational tools like Excel were identified as intimidating for students. Middle school students often lack proficiency with such tools, which can hinder their ability to enter and organize data in a spreadsheet format.

To overcome students' nervousness towards digital-based computational tools and transition from paper-and-pencil approaches, participants suggested adopting more user-friendly interfaces, such as Google Forms, to visualize data manipulation and enhance students' capabilities in data collection, creation, and analysis when designing the game. A less daunting interface would facilitate students' interactions with the software and increase their confidence in using digital-based computational tools. For instance, PF stated, "The cool thing about that is they can see it in Google Forms in the graphical way with those charts and graphs, but they can also build the spreadsheet and view the spreadsheet results and manipulate that data that way."

Facilitating understanding of abstract CT concepts through interactions with concrete representations in a game world

Participants mentioned that one teaching challenge was helping students understand CT concepts. Most CT concepts are too abstract for middle school students to fully grasp. Therefore, connecting CT concepts to familiar real-world situations within the game narrative is recommended.

> If we're talking about it from a pseudocode perspective, I think parameter becomes a hard word and where you might want to explicitly say, like, a parameter just means an input or a characteristic... So, like, a parameter could be color. And so then the argument when we call this function is red and this one is yellow, or if it's planting a tree, like the tree height is the parameter…I think that just written definition can probably get a little confusing. (PH)

Enlarging exposure to data cleaning and validation through complex datasets

Participants stated that due to time limitations and curriculum priorities, their teaching focus was primarily on data organization, manipulation, and basic graphing, with little emphasis on data cleaning and validation processes, as PG said, "We don't have as much emphasis on removing the irrelevant data or simplifying the dataset." To address this issue, participants suggested exposing students to complex data, as standard datasets typically presented to students lack complexity, such as outliers. This lack of complexity may hinder students' understanding of statistical concepts.

Conclusion

Although teachers are not traditional end users, we argue, in line with An and Cao's (2017) proposition, that when designing GBL targeting K-12 students, teachers should be considered typical end users. Our findings demonstrate that in-service teachers were highly engaged and made significant contributions to game design, particularly in the learning phase. Therefore, the study confirms the benefit of improving the game's usability and effectiveness when involving teachers as informants at the early stage of conceptualization (Khaled & Vasalou, 2014; Scaife et al., 1997). Additionally, participants provided insights on intrinsically embedding content in gameplay by offering valuable and relevant PCK, including knowledge of content and students, knowledge of content and teaching, and knowledge of content and curriculum. As Ball et al. (2008) argued that PCK could bridge content knowledge and teaching practice, we suggest that at the early stage of conceptualization, researchers and game designers could use PCK as a starting point to formulate appropriate and provocative representations for the content to be learned in the game. Finally, the study provides empirical evidence that there are distinct bodies of identifiable PCK (Ball et al., 2008; Shulman, 1986) in the context of applying CT to mathematics and science in K-12 settings.

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