Participatory Design of an Educational Game: In-Service Teachers' Contributions in Enhancing Students' Computational Thinking

Abstract

The current in-situ, descriptive case study explored in-service teachers' contributions and perspectives in the participatory design of an educational game for enhancing middle school students' computational thinking skills. The informant design technique was adopted, involving specific stakeholders at the stage of conceptualization. Data were collected from 8 in-service teachers at 9 middle schools through observation, a series of individual interviews, and focus-group interviews. The study results indicated that in-service teachers made contributions to the content design at the stage of conceptualization.

Keywords: participatory design, game design, in-service teachers, informant design

Introduction

Digital game-based learning (DGBL) is a promising learning platform that could be largely implemented in K–12 settings (Author, 2023). Research has shown that compared to conventional instructional approaches, games had better improvements on students' affective, cognitive, and motor learning outcomes (Hooshyar et al., 2021; Ke, 2016; Lester et al., 2014). Additionally, it has been commonly considered to have the potential to trigger motivation, which could result in optimal learning (Boyle et al., 2014; Eltahir et al., 2021).

Nonetheless, the process of the design and development of a high-quality DGBL is very complex and difficult (Hauge et al., 2020; Khaled & Vasalou, 2014). A growing number of researchers and game designers have explored various approaches to improving the quality of the DGBL. Prior research suggests the importance of involving stakeholders in the shaping of the artifacts (Schreier et al., 2012). 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)." Thus, participatory design (PD) that emphasizes the involvement of multiple stakeholders to enhance the reliability and validity of the game design was proposed (Ampatzidou & Gugerell, 2018; De Jans et al., 2017; Lanezki et al., 2020; Scaife et al., 1997).

However, with a rapidly expanding but still relatively small number of studies specifically referring to PD in DGBL design, more research in this area needs active study. In the specific case of DGBL design targeting middle school students, we still have limited knowledge about *when, how*, and *where* to use PD in game design and what contributions these design partners will make at a specific design stage. Therefore, the present study presents a case study that utilized PD for the design process of an educational game when engaging in-service teachers as design partners. We aim to explore how in-service teachers made contributions to the game design process when engaging as design partners at the early stage of conceptualization.

Literature Review

Teacher and DGBL

Students, rather than teachers, are normally considered end-users when they are targeted as game players for an educational game. However, as subject matter experts and educational professionals, teachers are familiar with the curriculum, the setting, and the difficulties of students' learning (Li, 2012). Meanwhile, teachers, as the most important practitioners in K–12 classrooms, play vital roles in implementing DGBL for teaching and learning. For instance, they make decisions about whether to adopt DGBL for their teaching (Akcaoglu & Kale, 2016). They also determine the best practices for how to design and implement lessons for students incorporating DGBL to optimize students' learning experiences (Akcaoglu & Kale, 2016; Li, 2012; Li et al., 2013). Thus, teachers should be regarded as typical end-users in K–12 settings because, without their supervision, a high-quality education could not be obtained.

According to prior research (Khaled & Vasalou, 2014; Sanders & Stappers, 2008; Webb, 1996), co-designers should master the domain content that was embedded in the game mission as well as knowledge of game design. Therefore, involving teachers, rather than students, as co-designers in the game design process tends to be more practical and feasible.

Participatory design for DGBL design

The theoretical framework of this study is PD specifically applied to the product design process. The roots of PD 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 PD, stakeholders are invited to cooperatively be involved with designers, developers, and researchers at specific stages of an innovation design process, which include the initial exploration of the problem, designing solutions, and evaluating proposed solutions (Hartson & Pyla, 2019; Muller & Kuhn, 1993).

As one type of PD, Scaife et al. (1997) proposed a methodological framework for informant game design, which includes four stages: 1) defining the problem; 2) identifying the product requirements; 3) creating and testing low-tech prototypes; and 4) testing high-tech prototypes. Various stakeholders were assigned to each stage in line with their knowledge, skills, and expertise, aiming to provide inputs that may shed light on the design process of product creation. Informant design is a strategy used to maximize the value of each stakeholder in the design process by considering the real situation that stakeholders might not have enough time, knowledge, or expertise to be qualified as central members of the design group (Scaife et al., 1997).

However, However, previous studies using informant design for DGBL design mainly involved either a wide range of stakeholders within the entire design process or the end-users (i.e., students) in the early design phase of conceptualization. Studies on the opportunities for involving specific stakeholders in the design of DGBL are still limited. The overarching question guiding the current study is: How did in-service teachers make contributions to the game design process when engaging as design partners at the early stage of conceptualization? Specifically, the two research questions addressed are as follows:

(1) What roles did in-service teachers play when involved in PD as design partners at the early stage of conceptualization for a DGBL project?
(2) What contributions did in-service teachers make when involved in PD as design partners at the early stage of conceptualization for a DGBL project?

Methodology

Research Design

We adopted a descriptive case study approach (Yin, 2009) to explore how in-service teachers as design partners made contributions to the process of educational game design. In this

study, each participant was considered a case that was used to describe the phenomenon and the real-life context in which it occurred (Yin, 2009).

Participant

We assembled an Educator Advisory Panel (EAP) consisting of 8 educators from 9 schools (one teacher works at three schools) in 3 districts. Participating educators include 3 instructional coaches, 4 middle and 1 high school mathematics, science, or computer science teachers.

Game design project: STEM+C

STEM+C aims to enhance CT competency for middle school students by increasing interest in data science among a more varied population of students. We will use Mineplex's Minecraft mod Lumberjack Tycoon, a learning management system (i.e., Canvas), and a node-based planning application to design and develop a more applicable game-based learning system in K-12 settings.

Data Collection

We video recorded the meetings that occurred from March 2020 to July 2021. Each meeting lasted between 40 minutes and 2.5 hours. A total of 9 meetings were recorded, yielding approximately 450 minutes of video data to analyze. All individual interviews and focus groups were transcribed verbatim for analysis. We used a semi-structured interview protocol to guide the interview process. In-field notes were taken while the researchers in the study were observing the participants' interactions and responses during focus group interviews. This data is used as a secondary source for us to examine the design process from the researchers' perspective.

Data Analysis

We conducted systematic coding followed by thematic analysis for the qualitative data (Attride-Stirling, 2001). After transcribing all the recorded videos, we developed an initial open-ended coding protocol highlighting notable patterns of coded narrative and the associations between contexts and learners' discourses. We noted and labeled the emerging categories and sub-categories, and the coding was constantly refined as the synthesis proceeded. Meanwhile, a cross-case pattern analysis of the individual case was conducted to verify the validity of the coding system (Miles & Huberman, 1994). Following that, we conducted a thematic analysis with the screen video archives and observation notes to identify additional themes that helped to extend or verify the patterns that emerged during the interview analyses.

Findings

Students' Challenges in Interpreting and Creating Graphs

During the interviews, participants expressed concerns about students' struggles with interpreting graphs and charts. They highlighted that when students encounter these visual representations of data, they face difficulties comprehending and analyzing them effectively.

> All of our students struggle with interpreting graphs, looking at charts and graphs. And when they see those things, they struggle with reading them. (Participant S1)

Two major factors contributing to such problems include (a) limited exposure to complex data and (b) time constraints and curriculum focus. Detailed information is discussed below.

Limited exposure to complex data. Two potential factors contribute to these challenges. First, teachers mentioned that standard datasets typically presented to students lack complexity, such as outliers, which may hinder students' understanding of statistical concepts. Second, there is the absence of exposure to data cleaning and validation processes in middle school. Below are some quotes to support these observations.

> I would say even in math when they look at typically the examples they're given or what they see, they're given pretty standard datasets. They're not given anything that has outliers that they have to look at. (Participant S1)

> But outliers and cleaning up data like that, we just don't do. (Participant P)

> And I don't think that that's something we really cover in the CS lesson. I think it's just a given that we assume that the data is valid and it's useful and we don't really get into that because we're more worried about manipulating it. So I think that's a part we skip over. (Participant S2)

Time Constraints and Curriculum Focus. Participants stated that due to time limitations and curriculum priorities, their teaching focus was primarily on data collection, organization, and basic graphing, with little emphasis on data cleaning and validation processes.

Students' Prerequisites and Challenges in Data Analysis Tools

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

> 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. (Participant H)

> I agree. Our kids don't see a lot of sheets. I'm seeing more of it now. (Participant S1)

These discussions indicate that the use of data analysis tools like Excel was identified as intimidating for students. Middle school students often lack proficiency with such tools, and this can hinder their ability to enter and organize data in a spreadsheet format.

To overcome students' apprehension towards data analysis tools, participants suggested the adoption of more user-friendly interfaces and scaffolding to reduce students' intimidation and enhance their data analysis capabilities. A less daunting interface would facilitate students' interactions with the software and increase their confidence in using data analysis tools.

Teaching Challenges in Virtual Learning and Student Participation

Participants raised concerns about challenges arising from virtual learning, such as reduced student participation and engagement. For example, Participant S noted that COVID-19 restrictions have compounded the issue, impacting students' motivation to engage in learning and complete their assignments, as quoted below.

> It's hard to get them to do things because they ... Especially right now we're struggling with participation, the kids who are at home and in a VLA or virtual learning setting, I think it's a global and universal problem right now that they're not doing the work. They're not getting there with us. (Participant S1)

However, participants also offered potential solutions to address these challenges and foster a sense of relevance. They proposed incorporating purpose-driven projects and contextualizing data analysis to make the learning experience more relevant and meaningful for students.

Conclusion

This study seeks to explore how teachers make contributions to the design process of DGBL when engaging as design partners. Overall, involving in-service teachers as design partners at the early stage of conceptualization could be an effective approach to improving the quality of the game. The study confirms the benefit of improving the game's reliability and validity when involving teachers as co-designers (Khaled & Vasalou, 2014; Scaife et al., 1997). In-service teachers proposed a great number of ideas to address the game design with respect to their knowledge, skills, and experiences.

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