

A Preliminary Study of Context Integration as A Determinant in The Effectiveness of Digital Mathematics Games

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Abstract: Contexts in the digital learning environment are one of the crucial components regarding students' motivation and positive attitude development toward content. Although there is not enough guiding information in the literature about how contexts should be, previous research has shown that even digital game contexts are effective in developing students' environmental awareness. To reveal the impact of contexts in the digital learning environment, it is necessary to consider the variables regarding the socio-economic and cultural status of the students. Therefore, it can be envisaged that the effect of digital game contexts may differ depending on students' experiences and social environments. For this purpose, digital games were designed in two different contexts in this research. In these digital games, two opposite contexts were selected. The first context was focused on saving nature and green energy. This context includes different levels of digital games on topics such as solar energy, reforestation, and clean water sources. The second context was focused on unregulated industrial development that negatively affects nature by ignoring it. This context includes different levels of digital games such as building thermal power plants, building chemical factories, and turning forests into fields. Apart from the contexts, the other variables in both games (i.e., gameplay, artistic structure, levels of problem parameters) are the same. At each game level, students were asked to solve mathematical problems regarding ratio-proportion. In this study, the preliminary findings, which were derived from a large experimental study, were presented. The participants of this study were 15 gifted eighth-grade students from Turkey. Among the participants, eight students played the digital game regarding the context of green energy, and the remaining seven students played the digital game regarding the context of unregulated industrial development. Preliminary findings showed that students were more interested in the digital game regarding the context of unregulated industrial development as it included interesting and beneficial topics such as energy generation and economic development. The resident perception of the citizens regarding the acute need for energy generation and economic development rather than saving nature and green energy since Turkey represents a developing country may explain this finding.

Keywords: Digital Game, Mathematics, Context, Problems, Environment Awareness

1. Introduction

Story (i.e., context) is presented in brief intervals to ensure that players understand essential concepts as the game progresses (Lim et. al., 2013). It is known that contexts (i.e. stories) are important in the learning process and have a positive effect on students' motivation and academic achievement (Hao, 2023). Moreover, contexts in the digital learning environment are one of the crucial components regarding students' motivation and positive attitude development toward content. Although there is not enough guiding information in the literature about how contexts should be, previous research has shown that even digital game contexts are effective in developing students' environmental awareness. To reveal the impact of contexts in the digital learning environment, it is necessary to consider the variables regarding the socio-economic and cultural status of the students. Therefore, it can be envisaged that the effect of digital game contexts may differ depending on students' experiences and social environments.

It is crucial to evaluate the effect of contexts on learning outcomes in terms of cultural differences in the digital game-based learning environment (DGLE). Previous research has shown that contexts related to environmental education have a positive effect on learning outcomes such as environmental awareness and attitude (Van Harskamp et al., 2023). Moreover, it was seen that the past studies conducted on environmental education positively and significantly improved students' awareness of the environment. (Ardoin et. al., 2018). It is also known that digital games related to environmental education are effective in developing positive attitudes in students (Janakiraman et. al., 2021). However, the most basic feature of digital games in these past studies (Ardoin et. al., 2018; Janakiraman et. al., 2021; Van Harskamp et al., 2023) is that the researchers focused on providing environmental awareness education rather than investigating the effect of contexts on learning outputs. While it can be argued that previous research underestimates the impact of digital game contexts on

learning outcomes, it may be useful to focus on the impact of digital game contexts on learning outcomes in terms of socio-economic and cultural norms through the country example.

In this study, Turkey has been selected as a country example. Turkey is a developing country and represents more Asian culture. Asian countries (e.g. Turkey) have a collectivist culture in which the decisions and value judgments of society are more important than those of individuals, whereas in European cultures individuality is at the forefront and individuals can make decisions on their own, their opinions are considered, and their self-constructs can be continuously developed. At this point, while Asian culture is resistant to change, European culture is change-oriented. (Klassen, 2004). Moreover, it is known that the environmental awareness of students in Turkey is not at the desired level (Savaşçı, 2020). Many researchers emphasize (Buldur et. al., 2018; Vural & Yılmaz, 2016) that Turkish national education is insufficient in terms of environmental education (Buldur et. al., 2018; Vural & Yılmaz, 2016). With the increasing need for energy in Turkey, citizens are concerned about foreign dependency on energy and the quality of life is decreasing due to expensive electricity bills (Ekşi et al., 2019; Clean Energy Foundation, 2022). As Turkey is a developing country, the resident perception of the citizens regarding the acute need for energy generation and economic development rather than saving nature and green energy is dominant (Clean Energy Foundation, 2022). It is also emphasized that there is an urgent need to ensure the information and active participation of citizens in Turkey in terms of social acceptance, especially regarding renewable energies (Demir & Ataöv, 2021). Therefore, exploring students' learning outcomes by focusing on environmental contexts (i.e., green/clean environment versus industrial environment) may reveal authentic, different, and in-depth findings, as Turkey represents a developing country with acute and resident perceptions of energy needs. At this point, it is thought that it would be useful to examine the effect of different contexts under GBLE within the scope of environmental education on learning outcomes in terms of socio-economic and cultural norms through the case of Turkey.

For this purpose, digital games were designed in two different contexts in this research through the case of Turkey. In these digital games, two opposite contexts were selected. The first context was focused on saving nature and green energy. This context includes different levels of digital games on topics such as solar energy, reforestation, and clean water sources. The second context was focused on unregulated industrial development that negatively affects nature by ignoring it. This context includes different levels of digital games such as building thermal power plants, building chemical factories, and turning forests into fields. Apart from the contexts, the other variables in both games (i.e., gameplay, artistic structure, levels of problem parameters) are the same. At each game level, students were asked to solve mathematical problems regarding ratio-proportion. Moreover, the digital games used in this study indirectly focused on environmental pollution through different contexts while teaching mathematical concepts.

In this study, the preliminary findings, which were derived from a large experimental study, were presented and it was aimed to reveal students' thoughts about different contexts within the scope of DGBLE. Moreover, the educational aspect of digital games was also examined. Therefore, the cognitive process of students while solving problems was observed.

2. Method

Since it was aimed to reveal the students' thoughts about different contexts in detail within the scope of DGBLE, the case study was chosen as the research design from qualitative research methods for this study. The case study design was chosen as it provides more in-depth analysis and findings from its natural environment through a situation or a case without any intervention (Yin, 2009). This research, which constitutes part of a larger experimental study, was conducted during the spring semester of the 2023-2024 academic year.

2.1 Participants

The participants of this study were 15 gifted eighth-grade students from Turkey. The age range of the students varies between 12 and 14. Eight of the students are boys and seven of them are girls. Participant students classified as gifted exhibit elevated scores on cognitive assessments, demonstrating superior intellectual capabilities in comparison to their age-matched peers. Consequently, these gifted students tend to display exceptional aptitude in domains such as visual arts, music, and academic pursuits (Bıçakçı & Bakırcı, 2021). The National Association of Gifted Children posits that subjects scoring within the top decile of the standard cognitive distribution are typically designated as "gifted". However, this threshold may fluctuate between the 1st and 25th percentiles, contingent upon the adopted theoretical framework or model of intelligence. A gifted student is characterized as one whose capacities in intellect, artistic expression, creativity, leadership, or general and/or

specialized abilities have been empirically determined by experts to significantly surpass those of their cohort (Ministry of National Education [MoNE], 2016).

For the purposes of this research, giftedness was operationalized as achieving a score exceeding 130 on the Anadolu Sak Intelligence Scale (ASIS), an instrument employed by the Turkish Ministry of National Education. The ASIS is an individually administered cognitive assessment comprising seven subtests, designed for children aged 4-12 years. Its verbal and visual components evaluate comprehensive cognitive functions, including reasoning, perceptual abilities, and working memory. The ASIS is regarded as one of the most robust individual intelligence measures globally, boasting internationally recognized psychometric properties (Sak et al., 2016; Sak et al., 2019; Tamul et al., 2020). The rationale for selecting participants from the 8th-grade level is that these students are in the formal operational stage and possess the necessary mathematical readiness in terms of the required learning outcomes related to proportional reasoning skills. Moreover, the participating students have previously taken many courses related to new-generation technology on Industry 4.0, augmented, virtual reality, and digital game design. Given the potential of gifted students to significantly influence future technological advancements and next-generation industrial developments, this study deliberately focused on 8th-grade gifted students as participants. The selection criteria were based on two primary factors: voluntary participation and the ability to articulate thoughts clearly. This deliberate sampling strategy was employed to ensure that the study population comprised individuals who are not only at a crucial stage of cognitive development but also possess the capacity to contribute meaningfully to the research objectives. The choice of 8th-grade students aligns with the developmental hypothesis that this age group has reached a level of cognitive maturity conducive to engaging with complex concepts and expressing sophisticated ideas, which is paramount for the study's investigative aims.

3. Data Collection Tools

3.1 Digital Games

In line with the purpose of the study, the digital games in this research were designed by the researchers. To explain the research environment in more detail, one of the contexts in digital games was the environmental context. In the environmental context, students were asked to organize the city by saving the city from environmental problems. In the industrial context, students were asked to develop the economy of the city and industrial development by damaging nature. In this respect, two different contexts were defined as opposite to each other. At the same time, in both contexts, students can visually observe the changes in the city. The problems presented in each context in GBLE, and the problems used in the game at each level were identical. To explain in more detail, the objects, animations, and mathematical problems used in both studies were the same. Only the context of the games was different.

This study focused on the possible advantages for gifted-students when utilizing a game-based learning environment for mathematics concepts and skills (i.e., rate/ratio and proportional reasoning). To select the problems used in the digital games in this study, past studies were analyzed to evaluate the concept of ratio-proportion from all aspects. In this study, the digital game was designed by considering the ratio-proportion problem types defined by Lamon et. al. (1993) and Van Dooren et. al. (2005). The problems at each level correspond to the problem types defined in these studies.

Gifted students played the digital games in the study individually or in groups of two or three. Among the participants, eight students played the digital game regarding the context of green energy, and the remaining seven students played the digital game regarding the context of unregulated industrial development. Eight of the students played the digital game individually (see Figure 1). The remaining seven students played the game in groups of two-two-three (see Figure 2 and Figure 3). In this way, both individual and group play of the game were evaluated. These digital games, each of which consisted of five levels developed for two different contexts (i.e., green/clean environment and industrial environment) varied between 15 and 45 minutes for each level. Meanwhile, the researchers were able to observe the behaviors and errors of the game-students interaction in detail. The digital gameplay was also recorded using Movavi Screen Recorder software. Then, focus group and individual clinical interviews were conducted with the students about the digital games they played.



Figure 1: Individual digital game playing



Figure 2: Playing digital games with a group of three students



Figure 3: Playing digital games with a group of three students

3.2 Researchers' Observation

Researchers' observation was made under the recordings of student digital game-playing videos with two main purposes. The first one is to examine the digital game from an educational point of view and to observe the effectiveness of the game. In other words, the difficulties experienced by students while solving problems and the strategies they use were examined. In this respect, the educational effectiveness of the educational digital

game was examined in terms of educational effectiveness. Moreover, researchers' observation was made to determine the missing and faulty parts of the digital game design. Since this research is part of a large study, researcher observation is crucial in determining the gameplay and in-game errors of the digital game at the design stage. However, the design phase of the digital game was planned to be discussed in another study.

3.3 Clinical Interviews

The purpose of the focus group and individual clinical interviews was to evaluate the students' views on the contexts (Koichu & Harel, 2007). In these interviews, students were asked about the shortcomings of digital games and the aspects of digital games that they like or dislike. The questions asked to the students during the clinical interviews are as follows:

1. Can you explain what are your general thoughts and first impressions about these digital games you played?
2. What do you find interesting about these digital games you play?
3. Can you list what are the most important features of these digital games?
4. What are your thoughts on the shortcomings of these digital games you play?
5. What are your criticisms, if any, about these digital games you have played?
6. Can you explain in detail how you solved the problem in this digital game you played?

In order not to guide the students, direct questions about the digital game context were not asked. In this way, students were asked to express their views on the digital game context themselves.

4. Data Analysis

During the research, the data collected was analyzed simultaneously. To do this, the transcripts were processed by selecting which of the collected data would be used, open, axial, and selective coding were performed, and appropriate themes were interpreted (Strauss & Corbin, 1990). In this study, a thematic analysis of the qualitative data was conducted. During the analysis process, the transcripts containing the raw data were read several times, and the data were divided into conceptual categories. Themes were reached by establishing relationships between the codes. Open coding was used as the first step of the thematization effort. Themes at a low level of abstraction were reached through open coding based on the research questions, concepts in the literature, terms used by students, and their thoughts on the environmental contexts. Axial coding was carried out by making a second pass over the superficial abstractions obtained through open coding. In this second pass, all the initial codes were related to each other. Thus, many closely related concepts were combined under a more general concept. Therefore, with axial coding, the codes were organized and related to discover the basic analytical categories. With the final coding, selective coding, the data were gone through for the last time and certain themes identified during the previous coding were reorganized. Thus, the main themes of the research were reached (Strauss & Corbin, 1990).

Preliminary findings

In the clinical interviews, the students were asked to identify the most important feature that interested them about digital games. The students tried to describe the most interesting aspects of digital games according to their features (see Table 1).

Table 1: Student views on the most interesting features of digital games

Student's view	<i>f</i>
Power plant building industrial factory	5
Training for a budget economically	3
Gamifying mathematics	3
Contains mathematical problems	3
Tree planting	1

Based on Table 1, it was revealed that student's views on the most interesting features of digital games were related to the industrial context. The students emphasized that in the game regarding the industrial context, power plant building regarding industrial factory and training for a budget economically were given. In this respect, gifted students stated that the digital game associated with the industrial context was more interesting

and valuable as it provided energy generation and budget management training economically. Gifted students also indicated that the digital games in both contexts were interesting and enjoyable since they included mathematical problems and gamified mathematics. On the other hand, only one gifted student mentioned that planting a tree was the best part of the digital game in the context of a green environment.

When asked about the missing parts of the digital games used in the research, it was observed that the students made critical comments on the gameplay of the digital games. In these digital games, especially the inability to determine the position of the tasks on the map and the lack of information on how to move the camera were emphasized by the students. However, only one student stated that since digital games are interesting, it would be better to have more levels in digital games and thus, they could try to complete these games for a longer time. In addition to all the findings, it was observed that these game levels were challenging even for gifted students and that the game was compatible and suitable even for group work. It was also observed that these digital games can be played with groups of one, two, and three players.

It was observed that most of the gifted students were able to determine the task related to the digital game, such as finding the type of solar panel, without performing mathematical operations. Although these students focused on the relationship between two different variables (i.e., money and energy), they stated in the interviews that they only chose the type of solar panel according to the dependent variable, namely energy. This situation reveals that students focus more on the dependent variable instead of the quantitative relationship. The following sample excerpt demonstrates the aforementioned situation.

S1: *"Since the C solar panel produces the most energy in this problem, we should choose this panel."*

On the other hand, it was observed that a few students initially ignored the data in the questions and the relationships between variables and chose solar panels randomly. These students tried to reach the answer by using a trial-and-error strategy among the options. These students used trial and error strategy only in the first digital game. In the other digital games, they were able to complete the tasks successfully by focusing on the problem situation and the relationships between quantities. Moreover, it was seen that almost all the gifted students used the proportional relationship while solving the mathematical problems in the digital games and they were able to use proportional reasoning easily. The example excerpt below shows the mentioned situation.

Researcher: *"Do you comprehend the problem?"*

S2: *"Yes, I try to find the answer by choosing randomly. Let me choose solar panel B and see what happens." "Oh, it didn't work, then I chose solar panel A. That didn't work either, so the answer is solar panel C (laughing)."*

S3: *"We aim to increase our money and, in this way, to do other tasks. Therefore, I should choose the panel that allows me to spend the least amount of money." I have to focus on the relationship between money and energy."*

5. Discussion and Conclusion

This study showed that the adaptation of the digital game environment based on mathematical problems regarding the concept of ratio-proportion in the literature drew the attention of gifted students and that they played this game with enjoyment and motivation. In these digital games, gifted students were able to determine the parameters as in mathematical activities and solve the problems based on these parameters. However, at the beginning of the game, some students tried to reach the result by just clicking the buttons without thinking deeply about the questions. It can be inferred from this that these students did not perceive the game environment as a mathematical problem at the beginning of the game. In their study, Alkan and Ada (2023) observed that in digital educational games, students did not read the instructions at the beginning and guessed the answers. From this point, it can be revealed that these students are not familiar with this kind of digital educational game environment. At this point, it can be deduced that these students generalize their usage habits related to digital games focused only on entertainment to educational digital games.

Preliminary findings showed that students were more interested in the digital game regarding the context of unregulated industrial development as it included interesting and beneficial topics such as energy generation and economic development. The students highlighted that the digital game related to the industrial context was particularly useful for learning how to build power plants regarding industrial factories and manage budgets efficiently. Gifted students found the game even more interesting and valuable as it provided training on energy generation and budget management economically. However, only one gifted student mentioned that planting

a tree was the best part of the digital game in the context of a green environment. Therefore, it can be claimed that gifted students are not very interested in the digital game related to the green environmental context and their attitudes towards this context are low. The reason why digital games related to the environmental context are of little interest to students may be associated with the lack of sufficient level of green environmental education in Turkey (Savaşçı, 2020). However, it is known that digital educational games are important in raising environmental awareness (Janakiraman et. al., 2021). However, both contexts aimed to develop environmental awareness in students. Even in the industrial context, the negative impact of unregulated industrial development on the environment can be observed. Similarly, the problems in the environmental context are related to rehabilitating the environment. However, it was observed that both digital game contexts caused students to focus more on energy production and energy needs instead of environmental awareness. At this point, it can be argued that both digital game contexts regarding the green/clean environment and industrial environment remain neutral in terms of encouraging students in terms of environmental awareness.

Based on these preliminary findings, it was revealed that the student characteristics of Turkey, which represents a developing country, were dominated by the view that contexts such as the economy and industrial development, that was, the industrial context are more interesting and useful than the green/clean environmental context. Moreover, the resident perception of the citizens regarding the acute need for energy generation and economic development rather than saving nature and green energy since Turkey represents a developing country may explain this finding (Clean Energy Foundation, 2022). The findings of a recent survey indicated that adolescents aged 15-17 in Turkey consider the high cost of energy and dependence on imported energy resources as the two biggest problems. This survey also showed that among Turkish citizens, adolescents are the cluster that is most concerned about energy external dependence and the cluster with the highest tendency to see oil as the main source of Turkey's energy external dependence (Clean Energy Foundation, 2022). On the other hand, the adoption of renewable energies is crucial for a sustainable future, and Turkey is no exception. To achieve this, it is imperative to ensure that citizens are well-informed about the benefits of renewable energy and actively participate in its social acceptance. As highlighted by Demir and Ataöv (2021), urgent action is needed to make this a reality in Turkey. Therefore, it is recommended that future studies on both environmental and academic learning outcomes of students at all educational levels through digital educational games focusing on mathematical concepts regarding various environmental contexts (i.e., green/clean environment versus industrial environment) be conducted especially in developing countries such as Turkey.

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