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Use of digital game based learning and gamification in secondary school science: The effect on student engagement, learning and gender difference

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Abstract This study aimed to identify the impact of a game based learning (GBL) application using computer technologies on student engagement in secondary school science classrooms. The literature reveals that conventional Science teaching techniques (teacher-centered lecture and teaching), which foster rote learning among students, are one of the major concerns in Pakistan Education system. This leads to student disengagement in science lessons eventually resulting in student absenteeism and dropouts from the schools. This study consisted of five stages: (1) examining the impact of Digital Game-Based Learning (DGBL) and gamification on engagement, learning and gender difference, and literature related to using DGBL models for instructional design; (2) planning learning activities and developing a GBL application based on a specific content in Science; (3) conducting an intervention with a sample of 72 participants of 8th grade (aged 12–15) in a low cost private school of Pakistan following quasi-experimental research framework; (4) observing behaviour and emotions of the participants during science lessons; (5) conducting pre and post tests to assess the learning outcomes of participants followed by focus groups discussion. Analysis from Friedman test, Mann-Whitney U test, and Wilcoxon Signed Rank test show that the GBL application has a positive influence on student engagement.

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However, GBL application was not equally effective for all students since girls outperformed boys in terms of engagement and learning outcomes. This study gives insights into the development of better educational games to promote student learning.

Keywords Student engagement · Game based learning · Gamification · Learning outcome · Gender studies · And secondary science education

1 Introduction

Integrating technology in education enhances student engagement and reduces the dropout rate. The dropout rate has remained one of the serious concerns in Pakistan (AlifAilaan and SDPI 2016). Presently, 24 million children aged 5–16 are out of school in Pakistan (i.e. 47% of all children in Pakistan) and nearly half of them are females[1] (AlifAilaan and SDPI 2016). The reasons for these children not attending and dropping out of schools are (a) parents reluctant to send their children to schools, (b) schools far from home (c) poverty; unable to afford the cost of schooling, (d) culture of early girls' marriage, (e) corporal punishment, (f) teacher absenteeism, and (g) low quality education (AlifAilaan and SDPI 2016; Chaudhry 2016). In general, the major reason associated with drop-out after two to three years of schooling is disengagement in the classroom (Finn 1989; Ulmanen et al. 2014). According to Pietarinen et al. (2014), 25% of students experienced reduced emotional gain at school and 20% of students were absent on a regular basis from school in OECD countries. These reduced engagement levels resulted in low achievement and negative attitude towards learning, hence leading to drop-outs from schools (Pietarinen et al. 2014). Research states following reasons that cause disengagement among students, particularly in Science classrooms: (a) learning science through conventional teaching approach promoting rote learning rather than concept building; (b) overcrowded classes; (c) insufficient number of periods for practical science; (d) lack of resources such as teaching materials, lab equipment, and time; (e) complex evaluation and assessment of learning outcomes; and (f) difficult science textbooks (Essays 2013; Kadbey et al. 2015; Li and Tsai 2013; Nyamubi 2017; Woldeamanuel et al. 2014). Most secondary schools also lack support from qualified technicians (Drury 2013). In addition, research suggests that culture is a major factor that affects the learning process of learners in Science. It was revealed that Asian learners perform better in learning Science than their Western peers as Asian learners acquire and are expected to maintain higher achievement motivation due to parental pressure and effective pedagogical approaches (Lee et al. 2008).

Prior to this research, a baseline survey conducted on 9th-grade students measuring the difficulty level of various subjects revealed that chemistry is a difficult subject to learn through conventional teaching methods. However, one of the propositions made by these students in considering pedagogical demands of teaching and learning was the use of educational technology (Woldeamanuel et al. 2014). Research shows that

[1] Sources: Annual Status of Education Report (ASER) 2015; EFA UNESCO Global Monitoring Report 2000–15; Government Allocations for Education in Pakistan (AlifAilaan) 2015; Pakistan Social and Living Standards Measurement Survey (PSLMS) 2014–15; Supreme Court of Pakistan, Constitution Petition No. 37 of 2012 (Petition Regarding Miserable Condition of the Schools); Pakistan Education Statistics 2014–15, Pakistan District Education Rankings 2016

secondary school teachers consider digital games as a useful tool in the classroom to strengthen student's motivation, engagement, and learning. Teaching with digital games is not a common approach in secondary education despite many studies on learning and motivational effects of digital games. It was revealed that only 25.2% of teachers in secondary education use digital games in the classroom, whereas 60.6% of teachers in primary education use digital games (Huizenga et al. 2017). To support the findings of Huizenga et al. (2017), Tatar et al. (2012) and Toussaint and Brown (2015) also suggest the use of digital games in helping students address their misconceptions, enhancing learning engagement and positively influencing the student learning. According to Hanus and Fox (2015), there is a limited empirical research on the effectiveness of gamification. However, the results of gamification elements in an educational context are mixed. In addition to this, empirical research conducted on gamification includes limited samples, lack of comparison groups, and a short period of intervention, singular assessment, and lack of validated methods (Hanus and Fox 2015). Therefore, with these views in mind, the present study intends to integrate gamification and DGBL in secondary school science; explore the effect of these learning approaches on student engagement, learning outcomes and its comparative analyses with conventional teaching approach (teacher-centered instruction); and study the gender difference in terms of these factors.

1.1 Definition of student engagement

Engagement can be defined as "psychological investment in and effort directed toward learning, understanding, or mastering the knowledge, skills, or crafts that academic work is intended to promote" (Newmann et al. 1992, p. 12). It is hard to motivate students to do the task without engagement referred to the length of an average session, i.e. the total time of a user spent/number of sessions (Stanculescu et al. 2016). There are three constructs of engagement that includes a) cognitive engagement, b) emotional engagement, and c) behavioural engagement. However, this research study is focused on emotional engagement concerned with emotions, indicating student interest in science; and behavioural engagement concerned with showing positive body language, attention, and confidence while initiating and completing learning activities in the Science class (Jones 2009a; Mo et al. 2012). It is to be noted that cognitive engagement is a less researched aspect which is associated with internal processes such as deep processing, cognitive strategy use, self-regulation, investment in learning, ability to think critically and making relationships with everyday life. Moreover, cognitive engagement has a positive impact on learning outcomes in students. Research shows that all three constructs of engagement are essential (Toll et al. 2016). However, teachers find cognitive engagement difficult to gauge since it is purely an internal process and is not easily observable within the classroom (Darr 2012). Therefore, cognitive engagement will not be studied in the present research.

1.2 Gamification and game-based learning

Two types of GBL are adopted in this study, i.e., gamification and DGBL. Gamification is defined as adding game design elements e.g. feedback, challenge, points to a non-gaming environment to promote active learning in conventional classrooms, increase student engagement and motivation, and help in achieving certain learning outcomes (Barata et al. 2013; Reiners et al. 2014). Also, Khaleel et al. (2016) defines gamification as the use of game elements in non-gaming context to boost engagement between humans and computers and resolve issues with high quality modern electronic applications. Almost all researchers admit that gamification can enhance engagement and motivation (Domínguez et al. 2013; Gok and Brendan 2016), that is., it builds up social relations and boosts contentment (Charles et al. 2011). Besides integrating gamification in education, GBL has also gained importance. For more than 30 years, GBL has been utilized in a variety of tasks and activities, and in learning engagement and motivation (Cojocariu and Boghian 2014). Mohamad et al. (2017) differentiate GBL and gamification. GBL aims at teaching knowledge and skills with an actual game, whereas gamification adopts certain game elements such as point, level, progression, reward, and status, etc. In the scope of this study, GBL is defined as learning through computer games designed purely for educational purposes. Digital GBL connects the teaching process with new learning technologies to promote cognitive changes and offer entertainment to the players (Cojocariu and Boghian 2014; Erhel and Jamet 2013). However, a lot of criticism has been received on DBGL and gamification, lately.

1.3 Criticism on the use of digital games based learning and gamification

Major risks associated with excessive use of Digital GBL in classrooms include limited time involved in completing a certain activity and repressed interactions among students (Cojocariu and Boghian 2014). However, research shows that GBL promotes a positive attitude towards learning; helps in retention and self-constructed learning; actively engage students in critical thinking; promotes learning engagement; and prompts the social and cognitive skills development (Cojocariu and Boghian 2014; Hung et al. 2014; Terri 2014). Recently, there has been quite a lot criticism of gamification (Domínguez et al. 2013; Knutas et al. 2014; Khaleel et al. 2016; Mohamad et al. 2017). Gamification might also fail to engage users and lead to participation issues if not embedded properly in a system (Burke 2014; Mohamad et al. 2017). Game elements are efficient tools to enhance engagement and learning. However, the impact of game elements on user engagement depends on different aims of gamified systems (Amriani et al. 2013; Gedera 2014; Mohamad et al. 2017; Schreurs and Alhuneidi 2012; Suh et al. 2015). For instance, Khaleel et al. (2016) reveals the following issues and challenges in application of gamification in his study; i) lack of game elements offering full explanations on learning content, ii) representation of learning content affecting the speed by which information is comprehended, and iii) difficulty in adjusting to a new learning environment. Also, González et al. (2014) concluded in their study that gamification caused boredom among students and led to a lack of interest and motivation to continue learning because students did not find the appropriate use of the system. In general, Gene et al. (2014), Graziela et al. (2014), Domínguez et al. (2013), Brühlmann (2015), Tan (2013) and Tracy (2014) admit that the implementation of gamification poses several issues and challenges in learning and found out those game elements such as challenge, competition, leader board, and interactivity cause problems in maintaining user motivation and engagement within the learning system in their studies. It is to be noted that gamification has to work long enough for some other processes to take over as the primary driver of value (Xu 2015).

1.4 Impact of games based learning and gamification on student engagement and learning outcomes

There is a likelihood of digital games to become an educational trend as they make their valuable applications in education (Chu and Hung 2015). Digital GBL is considered useful and attractive since it enhances learning achievement of students and promotes motivation and engagement as these digital games offer them an engaged and joyful learning experience (Chu and Hung 2015; Li and Tsai 2013). However, research reveals that the digital games do not necessarily promote learning achievement in students (Terri 2014*).* Out of 60 studies investigated on GBL, 22 (32%) studies resulted in better performance of the students as these studies defined the learning objectives precisely and targeted the specific learning content, contrary to 38 (56%) studies which measured the effectiveness of games on learning achievement (Chu and Hung 2015; Ke 2009). The short time period between the same tests, sampling techniques incorporated in these studies, teacher's bias towards a particular teaching method affected the outcome of such studies. However, extra time spent on the subject matter and the integration of game elements led to enhanced learning among students (Randel et al. 1992). Gamification is based on technology and is always applied on desktop, web and smartphone applications (Domínguez et al. 2013). Previously, research predicted that by 2014, more than 70% of Global 2000 organizations will have at least one gamified application while in the mean interval, gamification's production will generate a profit of $1.6 billion and will elucidate 23% of social media marketing budgets (Khaleel et al. 2016; Xu 2015). These predictions have come true. In present-day, gamified applications have already encompassed varied and distinct application areas including e-learning. To advocate the application of gamification, Domínguez et al. (2013) have implemented this approach in e-learning platforms in their study which seemed to have a positive influence on student motivation. Although, much effort is required in the design and implementation of the learning experience to be fully motivated and engaged since it is not trivial to achieve the positive effect (Domínguez et al. 2013). In addition to this, Khaleel et al. (2016) has studied the significance of applying game elements to his study to create an enjoyable learning environment and concluded that gamification can increase students' edutainment and enhance their understanding of learning materials. Indeed, much research has been conducted on DGBL and its potential to engage learners while very few have focused on the actual engagement of learners in an interactive context of DGBL (Byun and Loh 2015). It has been revealed that out of 256 DGBL studies reviewed, only 8(3%) empirical studies were about impact of game playing on learner's engagement whereas the rest of the studies were based on evaluating the effects of computer games on learning, exploring effective instructional game design, activity, and pedagogy, and investigating cognitive or motivational processes during gameplay (Byun and Loh 2015; Ke 2009). In this line of research, the present study tends to integrate DGBL and gamification in a classroom to study the influence on the learning outcomes and learning engagement of the research participants.

1.5 Digital games based learning and gender difference

Research reveals that teaching with digital games in secondary classrooms may enhance learning outcomes of the students as it appears to be effective for their short-term and long-term cognitive outcomes (Connolly et al. 2012; Wouters et al. 2013). However, it may not be equally effective for all students as the technology and learning preference of boys and girls may vary and seem to differ (Arnup et al. 2013; Admiraal et al. 2014). Usually, boys spend more time on gameplay than girls as it is their favorite past time, despite the differences (decrease) in time spent on gameplay between them (Homer et al. 2012). Moreover, boys prefer to play action games, whereas girls prefer to play virtual or simulation and puzzle games. However, gender gap does not exist with other game genres, such as role-playing games and adventure games (Admiraal et al. 2014; Hamlen 2011; Homer et al. 2012). The difference in preferences of gameplay is linked to a different motivation. Boys are more motivated to outperform girls in gameplay (with performance only and performance combined with mastery-achievement goals). Still, gender is confused with gaming frequency as several girls are persistent in playing games while several boys are non-gamers (Admiraal et al. 2014; Heeter et al. 2011). The research considers gender sensitivity essential towards educational games (Hsieh et al. 2015). Gender difference plays a significant role in DGBL approach when it comes to affecting learning outcomes (Dorji et al. 2015). Few authors have investigated whether a gender difference exists in gameplay or not. In a study of Klisch et al. (2012) and Chang et al. (2014), females outperformed males in terms of learning achievement and engagement via games. Contrary to this, Dorji et al. (2015) and Lester et al. (2014) found no significant gender differences in learning achievement of GBL in their studies. Though, extensive research has been carried out on the implication of gamification and GBL on learners' engagement and their learning outcomes. Still, Chang et al. (2014) and Dorji et al. (2015) have recommended that there is a need to conduct more research studies on the interaction between learning approaches and gender in terms of learning engagement and achievement and develop the strategies to promote gender parity in learning. In this line of research, the present study intends to investigate the influence of gamification and DGBL learning approaches on gender difference.

1.6 Games based learning for instructional design

GBL and pedagogy have come a long way in the last decade. Few educators are against the use of digital games in the classroom now, a contrast to the educators from 10 years back. Most of the teachers are satisfied with the use of digital games in classrooms. Research shows about half of them using digital games in classrooms for instruction at least once a week (Takeuchi and Vaala 2014). Teachers in their classroom have made considerable significant progress in the use of gamification. In the beginning, there were flaws in many studies with a limited use. However, recent studies drive towards the research design and different types of a game chosen for studies (Felicia and Egenfeld-Nielsen 2011). Research suggests that instead of focusing on the theories, educators should add a new approach to attract students and actively engage them in learning (Mohamad et al. 2017). To serve this purpose, Becker (2016) has presented various instructional design models for DGBL; one of them is Applied Model in designing instruction. In the Applied Model, Game Based Learning Instruction Design (GBL ID) approach has been adopted for the development of lesson plan template to enhance user engagement and learning in the present study. This model is implemented directly to the lesson that uses games. According to Mohamad et al. (2017), any desired lesson plan can be developed in six phases following GBL ID model for effective learning to take place and engaging learners in the learning process.

1) Consider the needs and characteristics of learners.
2) Consider the objectives, and goals of lesson or instruction.
3) Consider the acceptable evidence such as curriculum development in creating instruction that supports the progress of students to the lesson goals.
4) Design and conduct a predictive evaluation of the game, choose games that better fits the needs of learners, plan and develop tech support i.e., set the stage and plan time, space and resources; introduce the game and real life physical environment students will be in when they play the game.
5) Select instructional strategies and allocate resources to every student.
6) Plan and develop instruction, learning experiences, and reflection and game sessions.

This model combines most useful elements involved in all other models and approaches to give rise to a specific approach well suited in developing instruction that involves purely an educational or non-educational game (Becker 2016). Research shows that the following game elements such as *interactivity*; *rules*; *goals and challenges* (Adams and Dormans 2012; Bianchini et al. 2016; Kapp 2012; Morrison and Betsy 2014); *feedback and notification* (Kapp 2012; Khaleel et al. 2016; Kapp 2012; Measles and Abu-Dawood 2015; Stanculescu et al. 2016); *progression* (Morrison and Betsy 2014); *levels* (Bianchini et al. 2016; Khaleel et al. 2016); *points* (Bianchini et al. 2016; Stanculescu et al. 2016; Werbach and Hunter 2015); and *content presentation* have a positive influence on user engagement in DGBL environment (Domínguez et al. 2013; Hsieh et al. 2015; Klisch et al. 2012; Li and Tsai 2013; Prensky 2001; Shiratuddin and Landoni 2002; Yousef et al. 2014). Research also reveals that visual elements such as high-quality screen design, color, action, and animation; and audio in DGBL environment have the potential to directly affect the mood and emotions of learners and keep them behaviourally engaged during the learning process in DGBL environment (Byun and Loh 2015). However, there is a lack of research on curriculum's integration in and connection to the gamification to achieve certain instructional objectives. Hence, research is required to integrate gamification and GBL in the curriculum to achieve desired goals, as connecting gameplay to curriculum leads to effective transfer of knowledge in learners and turns the passive learning to the active learning process (Vandercruysse and Elen 2016). In this line of research, we adopted a GBL ID approach for implementation in science classrooms to enhance learning outcomes and learning engagement.

1.7 Present study- research questions

Since there is a limited research on the effectiveness of integrating GBL and gamification learning approaches to achieve desired set of goals, in the present study, we aimed to identify and analyse the impact of a GBL application of Science; *Patterns of Reactivity* developed for 8th-grade students on their learning outcomes, and engagement. The relationship between gender and these learning approaches in terms of learning engagement and learning outcomes were also analysed and explored in this study. The topic (*Patterns of Reactivity)* was based on a GBL application addressing the specific content of the secondary school science curriculum. This certain chapter was based on learning about and making discoveries of reactive and non-reactive metals, and formation of the reactivity series. In this research, digital learning activities were designed to promote engagement and learning through games. Two types of games based learning were considered in this research, i.e., DGBL and gamification.

Based on the literature review, we formulated the following research questions:

> RQ_1: Does learning through a GBL application developed for the students of secondary school science has a positive influence on their engagement in contrast to conventional teaching (involves teacher-centered teaching approach and rote learning)?
> RQ_2: Does learning through a GBL application developed for the students of secondary school science has a positive influence on their learning outcomes in contrast to conventional teaching (involves teacher-centered teaching approach and rote learning)?
> RQ_3: What is the difference in learning outcomes acquired through a GBL application of secondary school science between girls and boys?
> RQ_4: What is the difference in engagement with a GBL application of secondary school science between girls and boys?

RQ_1 and RQ_2 are sought to derive following hypotheses for result analyses where comparisons are drawn at 95% confidence interval ($\alpha = 0.05$): (a) Learning through a GBL application for the students of secondary school science will have a positive influence on their engagement in contrast to conventional teaching (Hypothesis 1). (b) Learning through a GBL application for the students of secondary school science will have a positive influence on their learning outcomes in contrast to conventional teaching (Hypothesis 2). For studying qualitative aspects of the present research, focus group discussion will highlight the issues on the use of GBL application in a science classroom. Therefore, RQ_3 and RQ_4 will explore the quantitative and qualitative aspects of gender to dig deep into the differences in learning outcomes via and engagement with GBL application.

2 Methodology

2.1 Research design

This research uses a non-equivalent quasi-experimental design and is predominantly quantitative in nature with some qualitative aspects. Two comparison groups were used in this study, considered as control groups and experimental groups. Control groups received conventional Science instruction (teacher- centered teaching approach involving rote learning) whereas experimental groups received a developed GBL application instruction on lesson plan similar to control groups' in this research study. Four sections of 8th grade represented control and experimental groups in this research study.

2.1.1 Sample

Selection of school was based on convenience sampling as computers were readily available and easily accessible within the school. A sample of 72 (aged 12–15 years) 8th-grade participants was drawn from a low-cost private school located in suburban area of Islamabad Capital Territory, Pakistan. The participants were randomly assigned to both the treatment groups ($T_{Girls} = 18$, $T_{Boys} = 13$) and control groups ($C_{Girls} = 18$, $C_{Boys} = 23$).

Profile classification of research participants

1) Social and Cultural Factors:
   Confidence level, self-discipline (self-control), and motivation to do well in Science classrooms favour girls in taking more interest towards studies than boys (Duckworth et al. 2015).
2) Preexisting knowledge of the content area:
   Preexisting knowledge of boys and girls are somewhat similar as both of them are at the equal level of pre-test (learning outcomes) of practical science subject.

2.2 Designing instruction and developing GBL application

This application was designed using one of the Applied Models in the instructional design of DGBL i.e. Games Based Learning Instructional Design approach (GBL ID), which was mentioned earlier in the literature review (Becker 2016). To effectively design instruction, we went through following phases.

2.2.1 Needs and learners

A baseline survey conducted prior to this study shows that students find chemistry (practical science) hard to understand. For this study, we have developed a GBL application with a specific content of secondary school science lesson, *Patterns of Reactivity.* This lesson includes the reaction of various reactive and non-reactive metals with acid, air and water; constructing reactivity series based on the extent to which these metals reacted with acid, water and air; and placing relevance on their everyday use. As stated earlier, learners have the varying socioeconomic background. We have designed this application for a low-cost private school and learners at home who are reluctant to attend schools.

2.2.2 Instructional objectives

As stated earlier, a game is more likely to achieve intended instructional objectives when gameplay is linked to the curriculum due to the actions that connect game content to the curriculum. This further stimulates transfer of knowledge in students and avoids learning process from being passive and dull (Vandercruysse and Elen 2016). Hence, the GBL application is based on the following learning goals as prescribed in the Pakistan National Curriculum of Science.

i) To identify and describe similarities in chemical reactions between metals and oxygen, water and acids.
ii) To recognize the differences in the reactivity of different metals.
iii) To use differences in the reactivity of metals to explain some everyday uses and occurrences of metals.

2.2.3 Acceptable evidence

Pre-test on learning outcomes of *Patterns of Reactivity* determined the actual knowledge of students before implementing the GBL application. A student learning has been measured on following learning outcomes after receiving instruction with GBL application:

1) Differences and similarities in reactions of various metals with water, oxygen, and acid.
2) Constructing reactivity series based on the extent of reactivity of various metals.
3) Discovering the benefits of metals and their daily usage in everyday objects.

2.2.4 Planning instruction and GBL application

We have considered following game elements in designing instruction to enhance learning and engagement: feedback, points, visuals, challenge, background music, interactivity, goals/objectives, progression, and levels. Furthermore, this GBL application helped students in achieving certain objectives:

i) To show that although metals react in a similar way with oxygen, water, and acids, some react more than others do.
ii) To establish and use a reactivity series of metal.

We have adopted a Unity 2D version 4.3 as a tool to design and develop this application. Based on the learning outcomes and goals of the lesson, three learning activities have been designed and embedded in the DGBL application, *Patterns of Reactivity.*

The first activity of an application comprised of videos and animations of reactive materials to foster student's retention of ideas. Reactions of 13 different metals with acid, water, and oxygen were shown in these videos followed by multiple –choice questions with three responses (See Appendix Fig. 6).

The second activity of an application was based on exploring the metals and their appropriate placement in an order of reactivity. Moreover, this activity prompts the user to place the metals on the rack in the correct order of reactivity (See Appendix Fig. 7).

The third activity which was purely a game of two levels in an application was based on constructing reactivity series (also See Appendix Fig. 8). The aim of these digital learning activities was to offer users with self- based learning with the least assistance possible. Table 1 shows the following game elements added in digital learning activities mentioned above to enhance user engagement and learning as previously reviewed in the literature section.

2.2.5 Planning time, resources and space: Intervention

The intervention spanned over ten sessions (five for girls and five for boys separately) of 30 min each over the period of three weeks. Treatment groups received instruction in the

Table 1 Game elements embedded in DGBL application on science

Game elements	Application
Levels	Two levels in a game shooting the balloon.
Progression	1) Rack at the bottom right of user's screen for elements' placement on the shooting of metal balloons in learning activity 3. 2) Rack at the right of the user's screen for items' placement on drag and drop in learning activity 2.
Points	Increasing scores on shooting the correct metal balloons.
Feedback / Help	1) Life loss on shooting the wrong balloon. 2) Information pops up. 3) Correct or incorrect responses.
Challenge	Completion of the task within limited time frame.
Audio	To engage users in DGBL application.
Interactivity	1) Drag and drop in 1st and 2nd learning activity. 2) Left and right keys movement and shooting in a 3rd learning activity.
Goal	Defined on top of the user's screen in all learning activities.
Visuals	Videos/Animations based Learning (practical science), content presentation.

computer lab on desktops via GBL application, whereas, the control groups received conventional teaching (which was a teacher-centered lecture or teaching approach) through their teacher in their own classroom. Figure 1 depicts the design of the intervention.

2.2.6 Selecting instructional strategies and allocating resources

Students have been assigned a worksheet as a scaffold alongside GBL application to help them in jotting down and making an observation of various reactions of metal which also helps them in constructing reactivity series (see Appendix B). Moreover, the

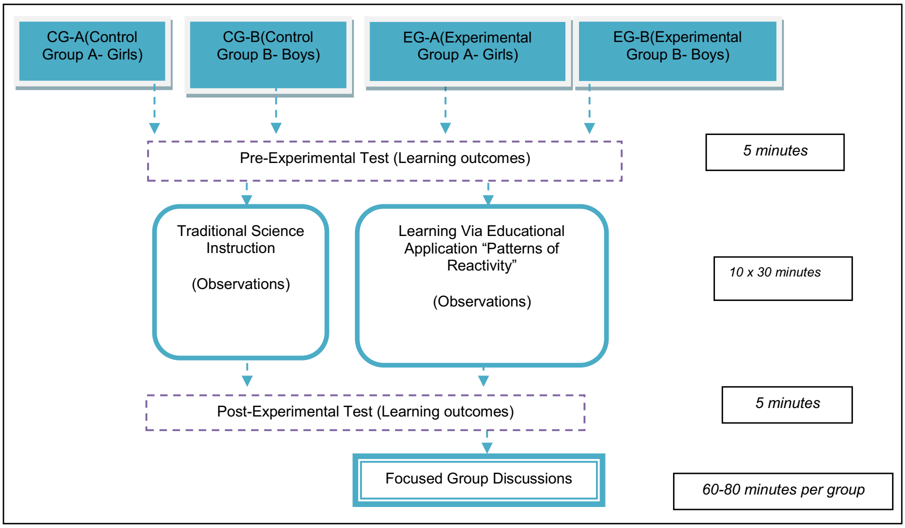


Fig. 1 Experimental design of this study

teachers have acted as an observer (gauging students' behaviour and emotions with the use of GBL application), evaluator (evaluating students as they are learning via GBL application) and a guide (instructing misleading students).

2.3 Data collection tools

Quantitative methods such as classroom observations, and pre and post-tests have been utilized to statistically analyse and compare means in this research study. Also, a qualitative method such as focused group discussion has been employed in this study to gather the insights and ensure the effectiveness of GBL application in Science instruction and its contribution towards effective learning in research participants (Hsieh et al. 2015).

2.3.1 Pre and post tests

The pre and post-tests were administered before and after the intervention, respectively. The purpose of these tests was to measure the learning outcomes of the participants. These tests measured and tested whether the research participants have learned important concepts and related facts, that is., assessing students' learning about differences and similarities in reactions of various metals with water, oxygen, and acid; constructing reactivity series based on the extent of reactivity of various metals; and exploring the benefits of metals and their daily usage in everyday objects. The tests comprised of a mixture of questions based on the selected learning outcomes from the National Science Curriculum. Various assessment approaches were adopted, e.g. true or false, fill in the blanks, multiple –choice questions, and descriptive answers to assess students' understanding of the topic. These ten items were focused on primary objectives (mentioned above) of lesson plan delivered through two different learning approaches, that is., via conventional teaching approach and GBL application approach. These developed tests took 10–25 min. All knowledge assessed was covered in the course that is, the lesson delivered during five instructional sessions (each 30 min long). Subject experts validated the questionnaire prior to the intervention (see Appendix A). The item type in pre and post tests was somewhat similar, except one item ('Steel is an alloy of'). At pre-test, this item was of type 'fill in the blank'. Almost no students could answer this question and their perception to answer it was different. Therefore, in post-test, we transformed this item to MCQ offering students to make a choice. These tests helped in making comparisons between groups, and both genders.

2.3.2 Classroom observations

In GBL environment, gathering data through observations is considered a highly suitable method to understand the engagement patterns of students (Hsieh et al. 2015), which further helps in determining the relationships between students learning and gaming process. The classroom observation tool used for this research was adopted from "student engagement walk-through checklist" prescribed by Jones (2009a), consisting of four items: positive body language, consistent focus, student confidence, and fun and excitement. A 5-point Likert scale with 1 being "very low" to 5 being "very high" was used to measure the level of student engagement demonstrated in the classrooms (see Appendix D). Teachers were trained to carry out observations in the class. Inter-rater reliability was ensured through rigorous training on using this tool prior to the study. Students were observed individually in a 10-min cycle during 30 min periods on a daily basis (see Appendix C).

2.3.3 Focus group discussion

To get further insights into the highlighted issues, two focus group discussions were held with a group of six girls and six boys from treatment groups, respectively. The aim of this discussion was to gather the details about the extent to which the participants were engaged with the use of GBL application. The discussion started with probe questions to make them feel comfortable in sharing their thoughts and experience on GBL application. Follow-up discussion inquired them about the qualities of learning application, their biggest misconception regarding the topic, effort exerted during instruction, and engagement with a learning application followed by an exit question. The responses were recorded and transcribed verbatim, which was later categorized under themes to support our research questions (see Appendix E).

3 Results

In order to fully understand the engagement patterns of students and investigate the impact of the developed GBL application on student achievement and gender difference, comparisons were drawn at 95% confidence interval ($\alpha = 0.05$). The nature of this study requires comparing student engagement of girls and boys within treatment groups and comparing engagement of the control and treatment groups.

3.1 Comparison of student engagement

The student engagement data obtained through observations were skewed for treatment and control groups, therefore, Friedman test which is a non-parametric test equivalent to one-way ANOVA with repeated measures was applied within treatment groups. Also, Mann-Whitney U test equivalent to Independent Samples t-test was applied between control and treatment groups. Following four engagement factors were analysed within groups and between groups.

3.1.1 Positive body language

The comparisons of engagement in terms of body language have been drawn within treatment groups, between control and treatment groups, and based on genders between these groups. Table 2 provides the means and standard deviations for the observed positive body language of girls and boys in both control and treatment groups.

A Friedman test was performed on treatment groups to measure the differences in their body language with time. This analysis indicated a significant difference in the body language of students who received GBL application instruction ($\chi 2 = 41.3$, $p = .000$) repeatedly measured during five instructional sessions.

A Mann-Whitney U test was performed to make comparisons in a body language of students within treatment groups, between control and treatment groups, and based on

Table 2 Means and standard deviations on positive body language for all learning approaches

Groups		N	Day 1 M	Day 1 SD	Day 2 M	Day 2 SD	Day 3 M	Day 3 SD	Day 4 M	Day 4 SD	Day 5 M	Day 5 SD
Control groups	Girls	18	12.00	1.64	12.06	2.51	11.83	2.07	11.83	2.07	11.83	2.07
	Boys	23	9.17	1.44	9.57	1.53	8.17	1.87	13.00	1.48	13.00	1.48
	Total	41	10.41	2.07	10.66	2.35	9.78	2.67	12.49	1.83	12.49	1.83
Treatment groups	Girls	18	11.72	1.53	13.28	0.96	13.94	1.26	15.00	0.00	13.33	1.53
	Boys	13	10.69	1.38	10.69	1.38	7.77	1.83	12.54	1.13	12.46	1.13
	Total	31	11.29	1.53	12.19	1.72	11.35	3.44	13.97	1.43	12.97	1.43

genders between these groups. This test indicated a significant difference in the body language of both genders between treatment groups. Follow-up comparisons revealed that no significant difference was indicated between a body language of both genders on first ($U = 73, p = .066, r = .85$) and fifth GBL application instructional sessions ($U = 83, p = .093, r =$ .30). However, the girls demonstrated significant positive body language on the second ($U = 19.0, p = .000, r = .33$), third ($U = 0, p = .000, r = .72$), and fourth sessions ($U = 18, p = .000, r =$ .85) as compared to boys.

Figure 2 depicts the trend of scores on the body language of boys and girls. As can be seen, GBL application instruction has consistently improved the body language of girls in contrast to boys.

In spite of boys (in the treatment group) scoring less on their body language, Table 3 shows that a significant difference was found between the control and treatment groups. Follow-up comparisons revealed that no significant difference was observed between the body language of control and treatment groups on the fifth day of the instructional session. However, treatment groups demonstrated significant positive body language on first, second, third, and fourth DGBL application instructional sessions as compared to those who received traditional instruction.

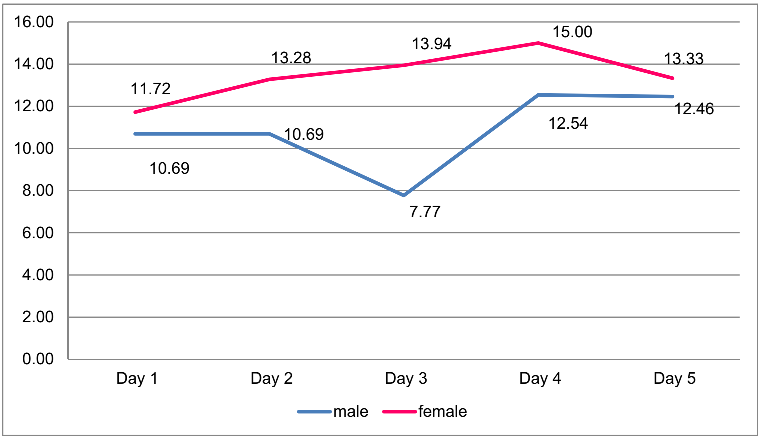


Fig. 2 Line plot depicting the overall trend of the observed body language of the students measured multiple times during intervention within the treatment groups

Table 3 Results of the Mann-Whitney U test to compare the treatment and control groups on body language

Positive body language		*N*	Mean rank	Sum of ranks	*U*	*Z*	*p*
Day 1	Control	41	32.3	1326	465	−1.97	.049*
	Treatment	31	42.0	1302			
Day 2	Control	41	30.5	1250	389	−2.83	.005**
	Treatment	31	44.5	1379			
Day 3	Control	41	31.9	1308	447	−2.16	.031*
	Treatment	31	42.6	1320			
Day 4	Control	41	28.9	1185	324	−3.64	.000***
	Treatment	31	46.5	1443			
Day 5	Control	41	35.5	1454	593	−0.51	.61
	Treatment	31	37.9	1175			

*p < .05, ** p < .01, ***p < .001

It is evident from Tables 4 and 5 that girls and boys in treatment groups demonstrated significant positive body language, in contrast to the body language of girls and boys in control groups, respectively.

3.1.2 Consistent focus

The comparisons of observed engagement on consistent focus have been drawn within treatment groups, between control and treatment groups, and based on genders between these groups. Table 6 provides the means and standard deviations for the observed consistent focus of girls and boys in both control and treatment groups.

A Friedman test was performed to measure the differences in the consistent focus of treatment groups on GBL application with time, $\chi 2 = 34.7, p = .000$. This analysis indicated a significant difference in the attention of students who received GBL application instruction.

Table 4 Results of the Mann-Whitney U test to compare the body language scores of the females in control and treatment groups

Positive body language		*N*	Mean rank	*U*	*Z*	*p*
Day 1	Control	18	20.0	136	−0.86	.39
	Treatment	18	17.0			
Day 2	Control	18	16.3	122	−1.29	.20
	Treatment	18	20.7			
Day 3	Control	18	13.0	62.5	−3.22	.001**
	Treatment	18	24.0			
Day 4	Control	18	9.50	0.000	−5.49	.000***
	Treatment	18	27.5			
Day 5	Control	18	15.1	100	−2.01	.044*
	Treatment	18	21.9			

*p < .05, **p < .01, ***p < .001

Table 5 Results of the Mann-Whitney U test to compare the body language scores of the males in control and treatment groups

Positive body language		*N*	Mean rank	*U*	*Z*	*p*
Day 1	Control	23	14.9	67	−2.84	0.005**
	Treatment	13	24.9			
Day 2	Control	23	16.0	91	−1.98	0.048*
	Treatment	13	23.0			
Day 3	Control	23	19.2	133	−0.58	0.56
	Treatment	13	17.2			
Day 4	Control	23	20.28	109	−1.41	0.16
	Treatment	13	15.3			
Day 5	Control	23	20.5	104	−1.60	0.11
	Treatment	13	15.0			

*p < .05, **p < .01, ***p < .001

A Mann-Whitney U test was performed to make comparisons on engagement factor in terms of the consistent focus of students within treatment groups, between control and treatment groups, and based on genders between these groups. In general, this test indicated a significant difference in consistent focus of both genders between treatment groups. No significant difference was found between both genders of treatment groups on a first ($U = 88, p = .236, r = .50$) and fifth day of GBL application instructions ($U = 78, p = .062, r =$ .33). However, comparisons revealed that the girls were significantly focused on the second ($U = 7, p = .000, r =$ .21), third ($U = 2.5, p = .000, r =$ .80), and fourth GBL application instructional sessions ($U = 60, p = .004, r =$ .81) as compared to the boys.

Figure 3 depicts the trend of scores on the consistent focus of boys and girls. As can be seen, GBL application instruction has aided in increasing attention span of girls in the beginning and then, consistently lowered their attention span till fourth instructional session. This graph illustrates a dramatic decline in the attention span of boys on a certain session after their increased attention span. Continuous learning via videos resulted in a low attention span of boys specifically on the third session of GBL application instruction.

Table 6 Means and standard deviations on consistent focus for all learning approaches

			Day 1		Day 2		Day 3		Day 4		Day 5	
Groups		N	M	SD	M	SD	M	SD	M	SD	M	SD
Control group	Girls	18	11.33	1.85	12.00	2.17	11.83	1.95	11.83	1.95	11.83	1.95
	Boys	23	8.70	1.49	8.96	1.22	8.00	1.78	12.39	1.47	12.39	1.47
	Total	41	9.85	2.10	10.29	2.27	9.68	2.66	12.15	1.70	12.15	1.70
Treatment group	Girls	18	12.94	2.46	14.61	0.50	13.17	1.69	13.00	1.46	13.33	1.53
	Boys	13	12.62	0.96	12.62	0.96	6.15	2.41	11.77	0.44	12.23	1.48
	Total	31	12.81	1.96	13.77	1.23	10.23	4.04	12.48	1.29	12.87	1.59

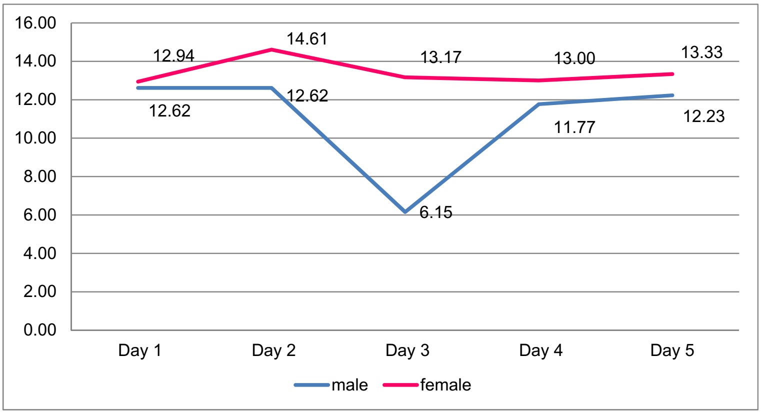


Fig. 3 Line plot depicting the overall trend of the observed consistent focus of the students measured multiple times during intervention within the treatment groups

Despite the low attention span of participants in the treatment groups on a few sessions of GBL application, they were significantly focused and paid attention to their instruction, on average as compared to the participants who received conventional science instruction.

A Mann-Whitney U test (indicated in Table 7) reveals that no significant difference was found between the control and treatment groups on third, fourth, and fifth instructional sessions. However, treatment groups demonstrated significantly higher consistent focus on the first and second day of GBL application instructions as compared to the control groups.

From Tables 8 and 9, it was further derived that girls and boys in the treatment groups were consistently attentive and focused on their instruction, in contrast to girls and boys of control groups, respectively.

Table 7 Results of the Mann-Whitney U test to compare control and treatment groups on consistent focus

Consistent focus		*N*	Mean rank	Sum of ranks	*U*	*Z*	*p*
Day 1	Control	41	25.4	1043	182	−5.20	.000***
	Treatment	31	51.1	1585			
Day 2	Control	41	24.4	1001	140	−5.70	.000***
	Treatment	31	52.5	1628			
Day 3	Control	41	34.4	1410	549	−0.99	.323
	Treatment	31	39.3	1218			
Day 4	Control	41	36.0	1477	616	−0.23	.815
	Treatment	31	37.1	1151			
Day 5	Control	41	33.5	1375	514	−1.45	.15
	Treatment	31	40.4	1253			

*p < .05, **p < .01, ***p < .001

Table 8 Results of the Mann-Whitney U test to compare the consistent focus scores of the females in control and treatment groups

Consistent focus		*N*	Mean rank	*U*	*Z*	*p*
Day 1	Control	18	13.9	80	−2.63	0.009*
	Treatment	18	23.1			
Day 2	Control	18	11.5	36	−4.15	0.000***
	Treatment	18	25.5			
Day 3	Control	18	15.1	101	−1.96	0.050
	Treatment	18	21.9			
Day 4	Control	18	16.17	120	−1.40	0.16
	Treatment	18	20.8			
Day 5	Control	18	15.1	100	−2.04	0.042*
	Treatment	18	21.9			

*p < .05, **p < .01, ***p < .001

3.1.3 Student confidence

The comparison of engagement factor in terms of student confidence has been drawn within treatment groups, between control and treatment groups, and based on genders between these groups. Table 10 provides the means and standard deviations of student confidence in control and treatment groups.

A Friedman test was performed to measure the difference in student confidence for treatment groups on GBL application with time, $\chi 2 = 15.2, p = .004$. This analysis indicated a significant difference in repetitive measures of confidence for those students who received instruction via GBL application.

A Mann Whitney U test was performed to make comparisons on engagement factor in terms of student confidence within treatment groups, between control and treatment groups, and based on genders between these groups. This test revealed a significant difference between both genders of the treatment groups. Follow up comparisons

Table 9 Results of the Mann-Whitney U test to compare the consistent focus scores of the males in control and treatment groups

Consistent focus		*N*	Mean rank	*U*	*Z*	*p*
Day 1	Control	23	12.2	5.50	−4.79	0.000***
	Treatment	13	29.6			
Day 2	Control	23	12.1	2.00	−4.93	0.000***
	Treatment	13	29.8			
Day 3	Control	23	21.5	81.5	−2.26	0.024*
	Treatment	13	13.3			
Day 4	Control	23	20.28	109	−1.44	0.15
	Treatment	13	15.3			
Day 5	Control	23	18.9	140	−0.33	0.74
	Treatment	13	17.8			

*p < .05, **p < .01, ***p < .001

Table 10 Means and standard deviations on student confidence for all learning approaches

			Day 1		Day 2		Day 3		Day 4		Day 5	
Groups		N	M	SD	M	SD	M	SD	M	SD	M	SD
Control group	Girls	18	8.61	2.30	10.72	2.35	11.22	2.34	11.22	2.34	11.22	2.34
	Boys	23	8.87	1.52	8.96	1.33	8.13	1.82	11.74	1.79	11.74	1.79
	Total	41	8.76	1.88	9.73	2.03	9.49	2.56	11.51	2.04	11.51	2.04
Treatment group	Girls	18	12.67	2.35	14.56	0.62	13.06	1.39	12.78	1.17	13.33	1.53
	Boys	13	10.46	1.61	10.46	1.61	7.62	3.48	10.85	1.34	11.62	1.80
	Total	31	11.74	2.32	12.84	2.34	10.77	3.66	11.97	1.56	12.61	1.84

revealed that the girls were significantly confident during all sessions of app instruction as compared to the boys i.e., first ($U = 53, p = .009, r = .46$), second ($U = 4.0, p = .000, r =$ .83), third ($U = 26.5, p = .000, r = .65$), fourth ($U = 33, p = .000, r = .66$), and fifth sessions ($U = 53, p = .006, r = .49$).

Figure 4 depicts a rising trend for girls at one point, which suddenly drops till day 4. Also, this graph illustrates a considerable slump for boys on day 3.

After day 3, the confidence level of boys started to increase. However, girls were more confident during app instructional sessions in contrast to boys.

A Mann-Whitney U test revealed a significant difference in the confidence of participants in the control and treatment groups. Follow-up comparisons revealed that participants of treatment groups demonstrated significantly high level of confidence on first, second, and fifth instructional sessions via GBL application as compared to the control groups (as indicated in Table 11) while no significant difference was found on confidence of participant between these groups, consecutively on third and fourth app-instructional sessions.

Similarly, *a significant difference was found in engagement factor in terms of confidence level for girls and boys in the treatment groups as compared with the confidence of girls and boys in control groups, respectively (as indicated in* Tables 12 and 13).

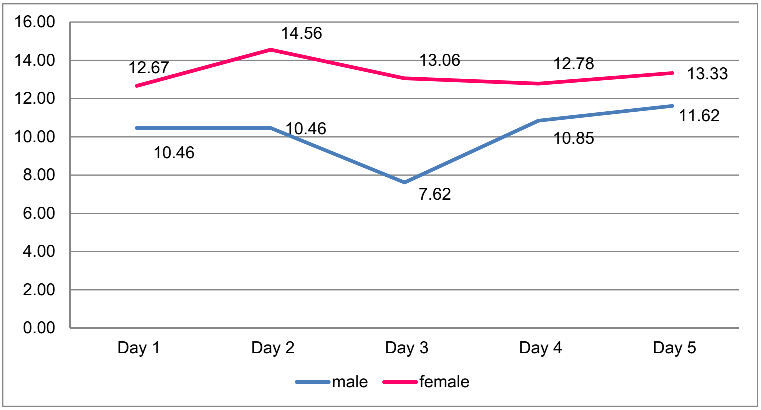


Fig. 4 Line plot depicting the overall trend of the observed confidence of the students measured multiple times during intervention within the treatment groups

Table 11 Results of the Mann-Whitney U test to compare the control and treatment groups on student confidence

Student confidence		*N*	Mean rank	*U*	*Z*	*p*
Day 1	Control	41	26.1	210	−4.88	.000***
	Treatment	31	50.2			
Day 2	Control	41	26.2	214	−4.85	.000***
	Treatment	31	50.1			
Day 3	Control	41	32.4	467	−1.93	.053
	Treatment	31	42.0			
Day 4	Control	41	34.8	566	−0.82	.414
	Treatment	31	38.8			
Day 5	Control	41	32.3	463	−2.00	.045*
	Treatment	31	42.1			

*p < .05, **p < .01, ***p < .001

3.1.4 Fun and excitement

The comparison of engagement factor in terms of fun and excitement has been drawn within treatment groups, between control and treatment groups, and based on genders between these groups. Table 14 provides the means and standard deviations of fun and excitement for the participants of both genders.

A Friedman test was performed to measure the difference in the fun and excitement of participants in treatment groups while playing with GBL application with time, $\chi 2 = 24.3$, $p = .000$. This analysis indicated a significant difference in repetitive measures of fun and excitement for those students who received instruction via GBL application.

A Mann-Whitney U test was performed to make comparisons on engagement factor in terms of fun and excitement within treatment groups, between control and treatment groups, and based on genders between these groups. This test revealed a significant difference between both genders of the treatment groups. Follow-up comparisons revealed

Table 12 Results of the Mann-Whitney U test to compare the confidence level of the females in control and treatment groups

Student confidence		*N*	Mean rank	*U*	*Z*	*p*
Day 1	Control	18	11.7	40	−3.90	0.000***
	Treatment	18	25.3			
Day 2	Control	18	10.0	10	−4.93	0.000***
	Treatment	18	27.0			
Day 3	Control	18	14.5	89.5	−2.33	0.020*
	Treatment	18	22.5			
Day 4	Control	18	15.14	102	−1.98	0.048*
	Treatment	18	21.9			
Day 5	Control	18	13.7	75	−2.84	0.004**
	Treatment	18	23.3			

*p < .05, **p < .01, ***p < .001

Table 13 Results of the Mann-Whitney U test to compare the confidence levels of the males in control and treatment groups

Student Confidence		*N*	Mean rank	*U*	*Z*	*p*
Day 1	Control	23	15.1	70.5	−2.66	.008**
	Treatment	13	24.6			
Day 2	Control	23	15.3	75.5	−2.50	.012*
	Treatment	13	24.2			
Day 3	Control	23	19.8	119	−1.02	.31
	Treatment	13	16.2			
Day 4	Control	23	20.57	102	−1.61	.11
	Treatment	13	14.8			
Day 5	Control	23	19.3	131	−0.62	.53
	Treatment	13	17.1			

$^*p < .05$, $^{**}p < .01$, $^{***}p < .001$

that boys had significant fun and they were significantly excited on the fifth session of app-instruction as compared to the girls, U = 52, p = .001, r = .56. However, the girls had significantly more fun and they were more excited on third (U = 29, p = .000, r = .63) and fourth (U = 10, p = .000, r = .85) instructional sessions as compared to the boys. Moreover, no significant difference in the fun and excitement was found in fun and excitement of the participants between these groups on first *(U = 98, p = .430, r = .13)* and second *(U = 114.5, p = .919, r = .017)* app instructional sessions.

Figure 5 depicts a consistent improvement in fun and excitement of girls. However, GBL app resulted in a sudden decline in fun and excitement of boys, at first and an increased fun and more excitement while playing with it, later on.

Fun and excitement for boys and girls were somewhat similar on days 1 and 2 of the intervention. The trend of fun and excitement for both girls and boys fell apart from day 2 onwards. The trend for girls jumped to 14.89 till day 4 and then went down to 13.33 suddenly on the fifth day. The trend for boys slumped considerably on day 3 and then, reached the peak on day 5 as compared to the girls' fun and excitement.

A Mann-Whitney U test performed on the fun and excitement of the participants in the control and treatment groups revealed a significant difference between them (as indicated

Table 14 Means and standard deviations on fun and excitement for all learning approaches

			Day 1		Day 2		Day 3		Day 4		Day 5	
Groups		N	M	SD	M	SD	M	SD	M	SD	M	SD
Control group	Girls	18	4.44	1.72	5.33	1.14	7.22	1.22	7.22	1.22	7.22	1.22
	Boys	23	8.13	1.52	8.70	1.15	7.52	1.88	11.87	1.29	11.87	1.29
	Total	41	6.51	2.44	7.22	2.03	7.39	1.61	9.83	2.64	9.83	2.64
Treatment group	Girls	18	12.06	2.46	11.67	2.09	13.67	1.28	14.89	0.47	13.33	1.53
	Boys	13	11.62	1.66	11.62	1.66	8.69	3.66	11.00	1.73	15.00	0.00
	Total	31	11.87	2.14	11.65	1.89	11.58	3.54	13.26	2.27	14.03	1.43

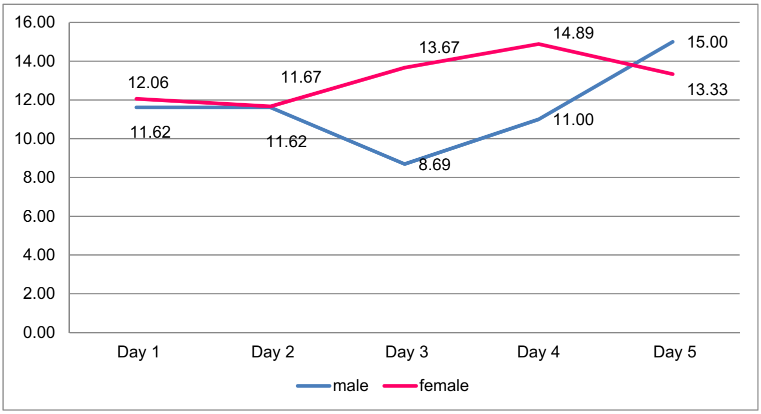


Fig. 5 Line plot depicting the overall trend of observed fun and excitement of the students measured multiple times during intervention within the treatment groups

in Table 15). Follow-up comparisons revealed that treatment groups had more fun and they were more excited while playing with GBL application during all apps-instructional days, i.e., day 1, day 2, day 3, day 4, and day 5 as compared to the control groups.

Similarly, further analysis from Tables 16 and 17 demonstrated that girls and boys had more fun and excitement while receiving GBL app instruction, in contrast to girls and boys who received conventional instruction.

3.2 Comparison of learning outcomes

The pre-test and post-test scores measuring learning outcomes were normally distributed for both control and treatment groups, therefore, a parametric test Paired Samples t-test was applied within the treatment groups, and Independent Samples t-test was applied between groups. Table 18 provides the means and standard deviations for pre and post-tests based on learning outcomes of girls and boys in both control and treatment groups.

Table 15 Results of the Mann-Whitney U test to compare the control and treatment groups on fun and excitement

Fun and excitement		*N*	Mean rank	*U*	*Z*	*p*
Day 1	Control	41	22.7	69	−6.47	.000***
	Treatment	31	54.8			
Day 2	Control	41	22.8	74	−6.44	.000***
	Treatment	31	54.6			
Day 3	Control	41	26.8	236	−4.58	.000***
	Treatment	31	49.4			
Day 4	Control	41	26.2	215	−4.84	.000***
	Treatment	31	50.1			
Day 5	Control	41	23.7	110	−6.09	.000***
	Treatment	31	53.5			

*p < .05, **p < .01, ***p < .001

Table 16 Results of the Mann-Whitney U test to compare the fun and excitement of females in control and treatment groups

Fun and excitement		*N*	Mean rank	*U*	*Z*	*p*
Day 1	Control	18	9.72	4	−5.03	0.000***
	Treatment	18	27.3			
Day 2	Control	18	9.50	0.000	−5.17	0.000***
	Treatment	18	27.5			
Day 3	Control	18	9.50	0.000	−5.18	0.000***
	Treatment	18	27.5			
Day 4	Control	18	9.500	0.000	−5.45	0.000***
	Treatment	18	27.5			
Day 5	Control	18	9.50	0.000	−5.24	0.000***
	Treatment	18	27.5			

*p < .05, **p < .01, ***p < .001

3.2.1 Comparison of students' pre-test and post-test within treatment groups

Paired Samples t-test was conducted to test whether the mean ranks of pre- test scores and post-test scores were equal within treatment groups. There was a statistically significant difference in the scores of pre-test and post- test, $t\ (29) = -\ 7.45,\ p = .000,\ d = 1.77$. This test revealed that the students performed significantly better on post-test i.e., after using and learning from GBL application, than their performance on the pre-test.

3.2.2 Comparison of learning outcomes between groups

Independent samples t-test was employed to compare the pre-test and post-test scores of girls and boys in treatment groups and between control and treatment groups. This test revealed that there was no significant difference in pre-test scores between males and females within the treatment groups, $t\ (29) = -\ 1.79,\ p = .084,\ d = 0.66$. However, the post-test scores of the females in the treatment group were statistically significantly higher as

Table 17 Results of the Mann-Whitney U test to compare the fun and excitement of males in the control and treatment groups

Fun and excitement		*N*	Mean rank	*U*	*Z*	*p*
Day 1	Control	23	12.9	20.5	−4.29	.000***
	Treatment	13	28.4			
Day 2	Control	23	13.2	28.0	−4.08	.000***
	Treatment	13	27.8			
Day 3	Control	23	17.8	133	−0.57	.57
	Treatment	13	19.8			
Day 4	Control	23	20.78	97	−1.77	.076
	Treatment	13	14.5			
Day 5	Control	23	12.0	0	−5.08	.000***
	Treatment	13	30.0			

*p < .05, **p < .01, ***p < .001

Table 18 Means and standard deviations of pre and post-tests based on learning outcomes for all learning approaches

Groups		N	Pre-test M	Pre-test SD	Post-test M	Post-test SD
Treatment groups	Girls	18	5.13	1.38	7.75	1.03
	Boys	13	4.32	1.04	6.34	1.41
	Total	31	4.79	1.29	7.16	1.38
Control groups	Girls	18	5.50	1.11	7.58	1.09
	Boys	23	5.17	1.40	6.61	1.53
	Total	41	5.31	1.27	7.03	1.42

compared to the post-test scores of males in the treatment group, $t\ (29) = -\ 3.193, p = .003, d = 1.14$. In conclusion, the girls performed significantly better in post-test after using GBL application than the boys, despite similar scores of girls and boys on the pre-test.

This test was also computed to analyse whether the mean ranks of pre and post tests are equal between control and treatment groups. Pre-test scores of the control groups and treatment groups did not show any statistically significant difference, $t\ (70) = 1.69$, $p = .094$, $d = 0.40$. Surprisingly, this test indicated no statistically significant difference in post-test scores between control and treatment groups, $t\ (70) = -.37$, $p = .71$, $d = 0.092$. In conclusion, there was no significant difference found in the pre-test and post-test scores of the students between control and treatment groups.

3.3 Students' discussion about their use of GBL application

A focus group was conducted separately with girls and boys to inquire about their use of GBL application in Science classrooms. In general, students were comfortable to share their views on their use of GBL application. As a result of this discussion, following four themes emerged from it:

i) Discussion of instructional design elements (game elements) used in GBL application.
ii) Discussion on a few aspects of instructional design involved in GBL application.
iii) Discussion of emotional and behavioural engagement with GBL application.
iv) Discussion on a few aspects of the disengagement posed by GBL application at times during intervention.

Students admitted that GBL application kept them behaviourally and emotionally engaged. They were more involved in this learning experience and they had more fun while learning, in contrast to their previous teacher-centered learning approach. Following noteworthy comments made by the participants were:

Female: 'Less effort was exerted in comprehending the concepts since it was easier to learn from app than conventional instruction approach…'

Female: '[… I put in some effort in game and activity because it involved deep thinking…]'

Female: 'Videos made me learn better and I can retain concepts for a long time….'

Female: I got involved and learned far better and memorised in a good way.'

Female: "*…the digital learning app kept me stay focused. No such thing distracted me.*"

Male: "*Through this digital learning app, I comprehended the concepts way better. Concepts were clarified compared to classroom instruction.*"

Male: "*Conceptual understanding was better. The way we were taught through the game and an activity was unique to me.*"

Male: "*…lot of interest developed for playing games. Our learning was real while playing activities and games*".

Female: 'It felt good. I find it fun to play.'

Male: 'I had fun interacting and learning using it'

Female: "*It was fun to learn*"

Female: '[…allows deep thinking for understanding concepts …'

Female: 'Though I put in some effort in game and activity because it involved deep thinking.'

One focus group admits that their use of GBL application resulted in a lack of engagement at times. The responses from focus group reveal that technical issues in software and hardware (such as malware attacks on PCs) caused disruption to the lesson.

Male: 'Videos keep getting stuck which distracted me a lot …'

Male: 'Videos were not playing at start…'

Male: 'Some concepts distracted me because, at that time, I could not understand them well at once.'

Students showed great interest in discussing the use and qualities of GBL application in their classrooms. Limited guidance or coaching, lack of interactivity and gaps in content delivery are drawbacks of this application, according to focus groups.

Male: 'The app was less interactive. I want it to be more interactive.'

Female: '…this app had failed to transfer deeper knowledge in me since this app lacked in definitions and description of some of the learning concepts...'

Female: 'Teacher should be there to guide us.'

Students admitted that content presentation of GBL application has attracted their attention and kept them interested throughout this learning process.

Male: 'The digital learning app attracted me a lot because it had animations (videos). The game (3rd learning activity) was most attractive of all.'

Female: "Animations (videos) attracted me a lot."

Female: 'Presentation of content in the app was very pleasing.'

4 Discussion

The present study examined the influence of a DGBL and gamification on secondary school students' engagement, and their learning outcomes. This study also investigated the differences in gender in terms of learning outcomes and learning engagement in DGBL environment. The quantitative analyses presented the comparison of learning outcomes and observed engagement levels of two different learning approaches, i.e. use of GBL application integrating several game elements for science instruction and conventional teaching approach promoting teacher centered teaching approach and rote learning of science concepts rather than concept building. Finally, the qualitative analysis presented the insights on the use of GBL application in science classrooms during focused group discussion.

In the present study, the use of DGBL and gamification learning approaches played a vital role in enhancing student engagement and understanding complex learning concepts in Science. As regards Hypothesis 1, we found that learning through a GBL application developed for the students of secondary school science have a significant positive influence on their engagement in contrast to conventional teaching. The impact of GBL application on student engagement was similar to previous studies (Hung et al. 2014; Lester et al. 2014; Tatar et al. 2012; Domínguez et al. 2013; Hsieh et al. 2015; Klisch et al. 2012; Li and Tsai 2013; Prensky 2001; Shiratuddin and Landoni 2002; Yousef et al. 2014), that is., integrating GBL and gamification learning approach in curriculum results in increased learning engagement and create an enjoyable learning experience for students. According to Khaleel et al. (2016), this learning approach can increase students' edutainment. So it can be concluded that integrating GBL and game elements such as challenge, progression, point, levels etc., in the curriculum to achieve desired learning goals can enhance student engagement. However, in contrast to Hypothesis 2, learning through a GBL application for the students of secondary school science does not have a significant influence on their learning outcomes in contrast to conventional teaching approach. In other words, research participants performed significantly better in a post-assessment in DGBL and a gamification environment as compared to their performance on pre-assessment, which is consistent with the findings of Chu and Hung (2015), and Li and Tsai (2013). Surprisingly, it was found that even after use of GBL application during science instruction for five 30 min long session, students' learning outcomes were somewhat similar and did not gain significantly, in contrast to those research participants who received conventional instruction (teacher- centered instruction), which is similar to the findings of Terri (2014), and Hanus and Fox (2015). In her unpublished study, Terri (2014) reported that students who were taught with conventional teaching approach gained significantly in terms of learning outcomes, despite its comparison with the use of educational technologies in classrooms. Hanus and Fox (2015) examined that some of the game elements caused harm to some educational outcomes in their study, despite the alignment of game elements with learning objectives. In other words, some of the common game elements resulted in a lack of engagement or motivation and reduced learning performance of the participants in their study (Hanus and Fox 2015). According to Terri (2014) and Klisch et al. (2012), factors such as short period of intervention, instructional time in class, access to technology, and reduced sample size might have contributed to this outcome. However, this study could lead to better results if students had attended all the classes during intervention because it may be possible that the low achievers could have benefited from it. These findings seem to differ from previous research of Khaleel et al. (2016) who concluded that gamification and GBL can enhance students' understanding of material and learning outcomes.

It is interesting to note that the digital learning application seemed to be more effective for girls rather than boys in terms of significant increase in engagement which supports the finding of previous research (Arnup et al. 2013; Admiraal et al. 2014), that is., the girls seemed to be more engaged than boys on the use of DGBL and gamification learning approach. According to Admiraal et al. (2014), Hamlen (2011) and Homer et al. (2012), the gender gap was found because of the varying preferences in the gameplay of girls and boys so different game genres lead to different engagement and learning outcomes in girls and boys. The current study also sets out to assess gender differences in terms of learning outcomes. The digital learning application has a positive influence on learning outcomes of girls than boys which corroborate with the findings of Chang et al. (2014) and Klisch et al. (2012), that is., girls outperformed boys in terms of learning outcomes, on their use of GBL and gamification learning approaches. According to Admiraal et al. (2014), boys are more motivated to outperform girls in gameplay (with performance only and performance combined with mastery-achievement goals). However, the present study has been unable to promote gender parity in terms of learning and engagement gains (Dorji et al. 2015; Lester et al. 2014).

Taken together, we explained these findings i.e. differences in learning outcomes acquired through and engagement with a GBL application of secondary school science between boys and girls, with respect to the research questions; RQ3 and RQ4. A possible explanation for these findings might be the influence of cultural and social factors on the research participants since previous research shows that girls surpass boys in a science subject all over the world as the primary emphasis of boys are on their final grades, whereas girls get a deeper knowledge and gain the understanding of the material (Economist.com 2015; Gnaulati 2014; Voyer and Voyer 2014), which is consistent with the present results. These findings further support the study of Voyer and Voyer (2014) which reflected the academic grades of over one million boys and girls from 30 different nations. In their study, Voyer and Voyer (2014) presented that girls get better grades than boys in every subject, including Science related fields because *'they tend to be more mastery-oriented in their schoolwork habits. They are more apt to plan ahead, set academic goals, and put effort into achieving those goals. They also are more likely than boys to feel intrinsically satisfied with the whole enterprise of organizing their work, and more invested in impressing themselves and their teachers with their efforts'* (Gnaulati 2014), supporting our findings. The findings of a present study are also consistent with a recent study by the OECD mentioned in Economist.com (2015). According to the OECD, 15 years old, boys and girl performed somewhat equal in Science but boys who strive hard are 50% more likely than girls to fall short of basic standards in science (Economist.com 2015). In addition to this, following three reasons gives justification on girls doing better than boys do at school despite gender disparity, according to The Economist (2015):

1) Reading is a foundation on which student learning is built and is connected to almost all school subjects. However, girls are more interested and proficient in reading than boys so boys suffer in studies.
2) Girls spend five and a half hours per week doing their homework, whereas boys are reluctant to spend most of their time on homework. Boys use the internet more and they are 17% more probable to play virtual and online collaborative games. Research shows that spending most of the time on doing homework given by a teacher leads to better performance in mathematics, reading, and science.
3) The boys think they are far cooler so they act rude and boisterous in class and do not focus on their studies thus do not perform well on tests. This is the reason why teachers mark them down.

Apart from the reasons stated by the author, the qualitative analysis (focus group discussion) in the present research also reflects the reasons for the lack of engagement in males and a significant gain in learning outcomes in females with their use of GBL application as discussed in sections 4.1 and 4.2.

4.1 Reasons for lack of engagement in males with their use of GBL application

In general, gamification elements such as visuals or content presentation, less interactivity and rare number of levels resulted in lack of engagement in males with their use of GBL application, which supports the research of Tracy (2014), as this author highlights that the most daunting task to motivate students is to set game rules, that is., games should have the elements of challenge and interactivity. However, previous examined studies indicate that the gamification elements, if embedded correctly, have a positive impact on its player and enhance engagement (Amriani et al. 2013; Gedera 2014; Schreurs and Alhuneidi 2012). According to Burke (2014), Domínguez et al. (2013) and Mohamad et al. (2017); at times gamification may fail to sustain user engagement. In other words, different game elements have different impacts on user engagement. Nevertheless, in this scenario, some of the students wanted to interact more with GBL application rather than just dragging and dropping elements or object. In the line of the current study, the reason for low scores on engagement in terms of student confidence, body language, and consistent attention and excitement may possibly be the use of videos that can cause distractions, especially for boys. The responses from focus group revealed that malware attacks on PCs caused disruption to the lesson as encountering technical problems (lost connections and hardware and software failures) had negative consequences on their learning outcomes, technology enhanced learning and engagement because failures in technology may block off any potential learning effect, which corroborates the findings of Admiraal et al. (2014), that is., their study backfired due to the confrontation of similar technical issues.

Moreover, continuously watching video demonstrations for three sessions on the reactions of various materials caused boredom among male students, as they wanted to play interactive virtual games instead of watching them. This problem affected their body language, confidence, and consistent focus negatively towards learning via GBL application. This was true for the bunch of students who considered time value and did not want to waste it (Whitton 2010). Students had difficulty in comprehending some of the learning concepts involved in videos based on the reaction of metals such as videos based on the reaction of metals with oxygen. The responses from focus group revealed that details and descriptions regarding metals' reaction, products' formation and reactivity series' formulation were missing and not clear. The levels of a game *shooting the balloon* were rare in number. Students completed them in less than 5 min, so they were sitting idle in their remaining time, which resulted in boredom in males, supporting the finding of Hanus and Fox (2015). According to Hanus and Fox (2015), engagement and interest decrease over time for research participants in a gamified system due to the relative novelty of gamification. Therefore, future developers and researchers ought to increase the number of levels of game and level of difficulty and then, identify its influence on its players. Apart from the videos-based learning, future developers can design virtual games on similar topics since boys tend to take more interest in these type of games. Moreover, future researchers should deduce strategies to avoid technical problems in research settings, as to maximise learning.

4.2 Reasons for significant gain in learning outcomes in females with their use of GBL application

Gamification elements such as progress tracking system, points, feedback/help, challenge, audio, visuals, interactivity (drag and drop), goal/objective and content presentation resulted in significant gain in learning outcomes and higher engagement in girls than boys which is consistent with the previous research (Byun and Loh 2015; Hsieh et al. 2015; Klisch et al. 2012; Li and Tsai 2013; Yousef et al. 2014), that is., these gamification elements integrated in a system have reflected significant gain in learning and engagement with students. The reasons for significant gains in engagement in terms of student confidence, consistent attention, excitement, and body language are associated with videos based learning (includes videos on the reaction of metals with oxygen, acid, and water), learning to build reactivity series and making real connections between them. Moreover, deep thinking has produced higher student engagement with GBL application and better understanding and easy memorisation of the learning concepts, e.g. establishing connections of reactive and non-reactive metals and their usage in everyday life. In addition to this, the analysis of the focus group shows that earning game points, information pop-up on metals' use, providing appropriate feedback on user's desired action, limited time frame to complete a game, background music, achieving a certain goal or an objective of a learning activity, having fun playing with a GBL application, and a pleasant and streamlined presentation of learning content contributed to enhanced learner's engagement with it, which is consistent with previous research (Byun and Loh 2015).

4.3 Limitations

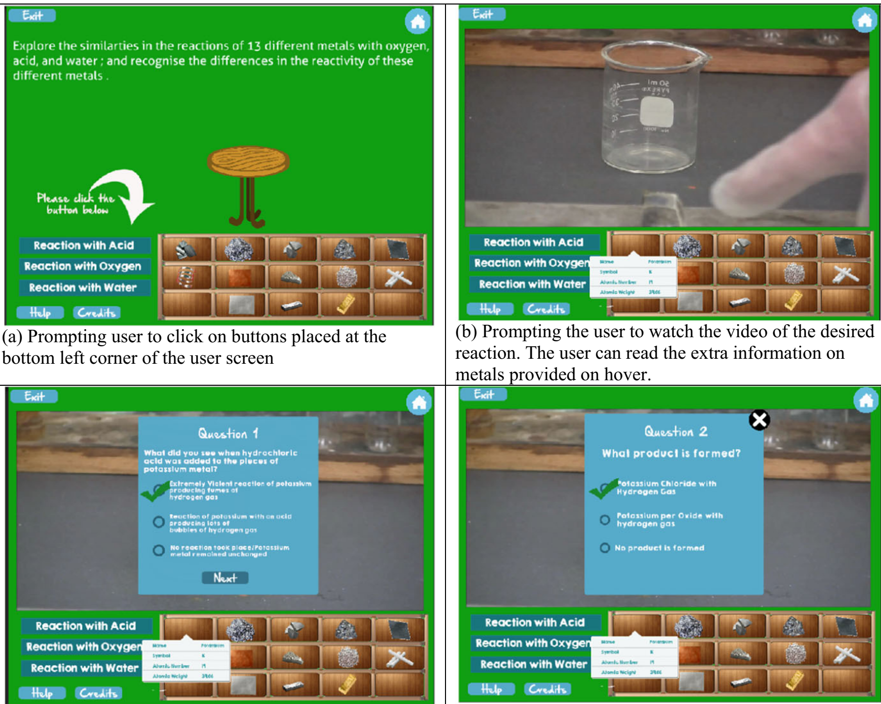
The present study can be made more effective if each observation cycle is spanned for at least 3 min instead of 10 min since, the best practice to gauge accurate observation and to examine the effect of technology in the classroom is to minimise the length of the observation cycle in future studies and increase the number of observers in each class. The results of this research study cannot be generalised because the classroom observations and content delivery made during intervention were limited to one school, single teacher and a few students (Alimoglu et al. 2014). While making observations, the real and observed behaviour of the students in the classroom sometimes may differ (Alimoglu et al. 2014). Apart from these limitations, limited guidance and lack of resources are other gaps in this study. It is to be noted that the GBL application in this study was designed for an individual user where the collaboration was not required and the teacher did not give any assignment or task to the students in the group, so verbal participation was not involved thus this factor is not measured in the present study. However, the future researchers may consider the verbal participation in their study.

4.4 Conclusion and future recommendations

Engagement is an essential component in the learning process. To enhance students' emotional and behavioural engagement, a GBL application has been embedded in a science instruction (Yousef et al. 2014). Identifying how student learning outcomes and engagement is influenced adds to the understanding of how teachers can recognize, analyse, and meet students' needs (Yousef et al. 2014). The main finding of this study is that the GBL application "*patterns of reactivity*" positively influenced the students' emotional and behavioural engagement in the science classroom. In general, the comparative analyses with conventional Science instruction revealed that the GBL application has a significant positive impact on learners' engagement. However, students fell short of achieving the learning outcomes of science lesson with a GBL application. Nevertheless, the study significantly contributes towards engagement and gender, thus indicating a significant gain in learning outcomes and increase in engagement of girls than boys. Despite the finding that the use of GBL application did not show significant improvement in the learning outcomes of the participants, this study may have taken an important step towards investigating and measuring the relationship between learning approaches and the attributes of a learning process that can affect effective learning such as student engagement and gender difference. Since boys lacked behind girls in terms of learning outcomes and engagement in present research, therefore, we will work on bringing knowledge and engagement levels of boys with the girls' in future research by designing a game that favours boys and girls equally. However, girls seem more interested in the use of technology in this study so this could be an alternative solution for those girls who are not allowed to attend the school. This study has provided an economical, high quality and reliable solution in a low-priced private school, which if incorporated in future studies can enhance retention and eliminate illiteracy, particularly in Pakistan. Therefore, the future researchers can implement these strategies to provide quality education accessible to everyone, and everywhere and promote the education of girls irrespective of their culture and socioeconomic background.

The current study also suggests certain recommendations to future developers, education advocates, and researchers. The recommendations suggested at teachers and educators level are to create student-centered classrooms and to offer teachers formal training programmes on the use of digital games in classrooms for learning purposes since teachers learn to instruct with digital games through informal means such as by self-teaching and from fellow teachers. As a consequence, '*teachers may not be getting exposure to the broad range of pedagogical strategies, resources, and types of games that can enhance and facilitate digital game integration*' (Takeuchi and Vaala 2014). Moreover, this study recommends future developers and instructional designers to integrate content specific learning outcomes in digital games properly, considering only those game elements which enhance learning and engagement equally among girls and boys irrespective of the game genres. Furthermore, this study also suggests future researchers to bridge the gender gap and promote verbal participation through GBL approach. With significant results in these studies, much more evidence is needed to support the findings of the present study.

Appendices



(a) Prompting user to click on buttons placed at the bottom left corner of the user screen

(b) Prompting the user to watch the video of the desired reaction. The user can read the extra information on metals provided on hover.

(c) After video stops playing, quiz pops up where the user is required to answer the multiple choice question with 3 responses

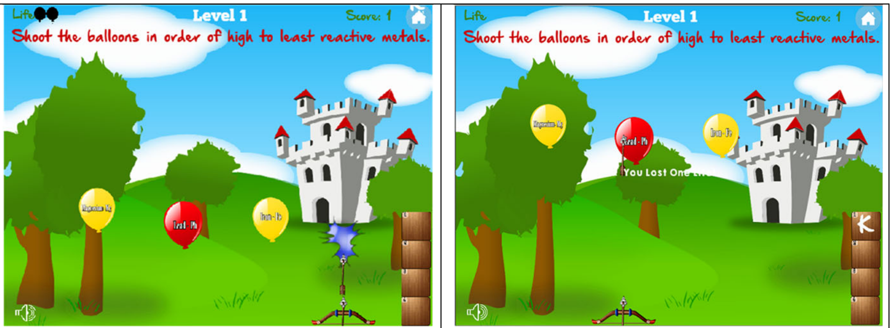
(d) The second question will pop up with 3 responses. The questions will give an appropriate feedback on user's action.

Fig. 6 Flow of first learning activity based on the reaction of metals in a game-based learning application

(a) Prompting the user to drag and drop items from a bedroom scenario and place in the rack in the correct order of reactivity. In the case of correct placement of metals, positive feedback pops up on the user screen.

(b) Prompting the user to click the question mark icon to open a pop-up with general information on the item and its composition.

Fig. 7 Flow of second learning activity in a game-based learning application based on order of reactivity



(a) On correct shooting of the metal balloon, the score increments

(b) On incorrect shooting of metal balloon, one life of a user is lost showing a message on user screen,“ you lost one life”

Fig. 8 Game SHOOTING THE BALLOON based on reactivity series in a game-based learning application

A. Learning outcomes test

Table 19 Pre-test and post- test assessing learning outcomes of topic *‘Patterns of reactivity’*

Item’s type	Pre-test	Post-test
Item 1: True/False	Gold is a non-reactive metal.	Silver is a non-reactive metal.
Item 2: MCQ	Water pipes are made of a) Copper Only; b) Copper and Iron; c) Zinc Only.	1) Table salt is composed of a) Zinc, b) Magnesium, c) Potassium, d) Sodium.
Item 3: True/False	Drinking Water is composed of Zinc element.	Drinking Water is composed of Zinc element.
Item 4: True/False	Potassium metal is highly reactive in nature	Sodium is less reactive than Potassium.
Item 5: True/False	Hydrochloric acid is dangerous in nature i-e; it burns skin on contact	When Calcium reacts with hydrochloric acid, fumes of Hydrogen gas are formed.
Item 6: Fill in the blank	Which gas is evolved when Zinc reacts with Sulphuric Acid? $Zn + H_2SO_4 \rightarrow$	

Table 19 (continued)

Item's type	Pre-test	Post-test
		What product(s) is/are formed when a metal reacts with oxygen? Copper + Oxygen.→
Item 7: Descriptive Question	What causes "Rusting"?	A boy adds pieces/chunks of Zinc in a balloon. He puts the balloon on the mouth of a flask. The flask contains 6 ml of Hydro Chloric Acid. After a few seconds, the balloon starts to inflate forming Zinc Chloride. What do you think how was the balloon inflated? What is the reason behind balloon inflation?
Item 8: Fill in the blank/ MCQ	Steel is an alloy of.	Steel is an alloy of a) Iron, b) Zinc, c) Copper, d) Silver.
Item 9: True/false	Platinum shows a reaction with hydrochloric acid	Lead burns in the air on bringing it closer to the flame.
Item 10: fill in the blank	Human bones are made of_____________ element.	Match the metals with numbers in order from highest to least reactivity. [Four metals (Zinc, Magnesium, Silver and Potassium) are mentioned. The user has to match it with its number on reactivity series.]

B. Worksheet

Metals	Reaction with water/Oxygen/Acid	Order of reactivity	Products

C. Tool for measuring classroom observation

ID	Positive body language			Consistent focus			Student confidence			Fun and excitement		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd

D. Walk through checklist (Jones 2009a)

	Very High	High	Medium	Low	Very Low
Positive Body Language	☐	☐	☐	☐	☐

Students exhibit body postures that indicate they are paying attention to the teacher and/or other students.

	Very High	High	Medium	Low	Very Low
Consistent Focus	☐	☐	☐	☐	☐

All students are focused on the learning activity with minimum disruptions.

	Very High	High	Medium	Low	Very Low
Student Confidence	☐	☐	☐	☐	☐

Students exhibit confidence and can initiate and complete a task with limited coaching and can work in a group.

	Very High	High	Medium	Low	Very Low
Fun and Excitement	☐	☐	☐	☐	☐

Students exhibit interest and enthusiasm and use positive humor.

E. Focus group discussion

Indicative questions:

1. What are your thoughts on the learning app that you used in the classroom?
2. How was your experience?
3. Give at least three strengths and three weaknesses of the app? Explain in detail.
4. What did you learn from this learning process?
5. Did you find this learning app relevant to your curriculum?
6. What were your biggest misconceptions about science?
7. Did this learning app help you address the misconceptions you had previously in Science especially related to "patterns of Reactivity"?
8. Did you get distracted during work? Why did you get distracted or why not?
9. How much effort did you exert in this work? Which things/parts in an app kept you stay focused for a long time? Why?
10. How engaging did you find this learning app?
11. What did you learn from it?
12. Anything you wanted to add.

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