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# The Use of Educational Games in High School Chemistry Learning in West Java Province

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**Abstract:** The implementation of games in chemistry classes has provided an interesting and alternative teaching method and allows students to learn in a more entertaining way compared to traditional learning process. The game-based learning approach is divided into three approaches, namely game-based learning or educational games, gamification, and game-assisted learning. Many chemistry games have been constructed in recent years to review and strengthen various chemistry topics; therefore, it is expected that Chemistry teachers in high schools in Indonesia, especially in West Java province implement educational games in the learning process. For that reason, it is necessary to perceive an overview of the use of educational games in Chemistry learning in secondary schools in West Java province. Survey research was carried out using a random sampling technique. There were 99 chemistry teachers from 91 high schools spread across the province of West Java who voluntarily participated in the online survey. The result of the analysis obtained that 35% of chemistry teachers in the province of West Java have implemented gamification and learning using game assistance. On the contrary, game-based learning has never been implemented in Chemistry learning process in secondary schools in West Java province.

**Keywords:** Educational games; Gamification; Game-assisted learning

## Introduction

The new generation known as millennials have grown up in the technological revolution, and as such, they rely on electronic devices for many aspects of their lives. For this reason, the learning process has been adapted to the application of technological devices using cell phones, tablets and laptops to increase student motivation and interactivity in class. The most frequently developed non-traditional teaching methods are reverse class, gamification, case studies, social media, and independent learning (Llanos et al., 2021). Mobile app-based games for learning in chemistry education have also increased in popularity in recent years given the ubiquitous use of smartphones for communication, recreation and more (Lees et al., 2020). In addition, (Da Silva Júnior et al., 2017) states that games are an excellent active learning method, and their use in chemistry classes has provided an interesting and alternative teaching method and allows students to learn in a more entertaining way than traditional learning formats.

Gamification methods improve learning ability by using gaming experiences in non-gaming contexts. This method is based on constructivist learning because the influence of games on the cognitive, emotional, and social domains of players leads to increased motivation in the learning process (Llanos et al., 2021). In line with the opinion conveyed (Yenikalaycl et al., 2019) that games can be used effectively as pedagogical tools in reconstructing learners' knowledge. Educational games provide reinforcement of knowledge and repetition of lessons in a more relaxed environment and provide opportunities for learners to express themselves in a better way. In literature, several gamification techniques have been developed to gamify learning experiences such as points, rewards, badges, leaderboards, scoreboards, challenges, levels, or feedback. Game-based learning activities are often seen as a new approach to increase learner engagement and encourage

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more active learning (Ponikwer et al., 2021). In addition, through the competitive nature of gaming, learners often find themselves taking greater responsibility for their learning. Other experts such as Salen et al. (2004) defines *gaming* as a system in which players engage in artificial conflicts, defined by rules, that produce measurable outcomes.

Plass et al. (2020) explained that the game-based learning approach is divided into three approaches, namely game-based learning or educational games, gamification, and game-assisted learning. Gamification involves adding certain game features, primarily involving reward systems and narrative structures, to existing (nongame) learning environments to be more motivating. Game-based learning means learning is redesigned to make it more engaging, meaningful, and, ultimately, more effective for learning than nongame or gamified tasks. Whereas game-assisted learning meant that learning activities could be redesigned, but game features were only used in subtle ways to create a fun experience but not a complete game, the learning approach was changed to include some game features in instructional learning. In Table 1, we can see the different characteristics of game-based learning.

**Table 1.** Characteristics of Game-Based Learning

| | Learning Activities | Game Features | Example |
|---|---|---|---|
| Gamification | Largely unchanged | Most use extrinsic rewards | Gamified worksheets |
| *Game-assisted learning* | Redesigned to be more relevant, meaningful, and engaging | Most uses of rewards are intrinsic | Simulation with fun feedback |
| Game-based learning | Redesigned to be more relevant, meaningful, and engaging | Use of various game features | Educational games |

In line with the results of research conducted by Yenikalaycl et al. (2019) which showed that learners also stated that games increase their motivation in learning. The development of computer educational games can combine the educational quality of games and interesting technology, making the traditional chemistry teaching process much more interesting and effective for learners when absorbed with interactive technology tools (Da Silva Júnior et al., 2017).

Another proposed innovative learning strategy is the use of electronic games (also referred to as serious play or game-based learning) in education. Many of these games address both the cognitive and affective dimensions of knowledge, to enable learners to adapt learning to their cognitive needs and interests and to significantly improve learners' motivation and learning outcomes (Da Silva Júnior et al., 2020) included in Chemistry learning.

Chemistry is one of the important branches of science because it is everywhere and allows learners to understand many things that are happening around them. Unfortunately, many learners experience the chemistry curriculum as something abstract, difficult to learn, and unrelated to the world they live in (Da Silva Júnior et al., 2020). This can happen because teachers do not link multilevel representation or intertextuality of Chemistry content in learning to students in schools. Likewise, Chemistry textbooks used in schools are not good at explaining the intertextuality of Chemistry content, such as the results of Bucat and Mocerino's research in (Gilbert et al., 2009) which shows that problems arise due to limitations of two-dimensional (2D) representation and carelessness in diagrams in textbooks.

According to Cheng and Gilbert in (Gilbert & Treagust, 2009), the representation of chemical concepts is like scientific concepts in general, inherently multimodal, which involves a combination of more than one mode of representation. As a result, successful chemistry learning involves constructing mental associations among levels of macroscopic, submicroscopic, and symbolic representations of chemical phenomena using different modes of representation.

Chemical phenomena are initially explained from the macroscopic level, starting with how a person experiences chemistry. However, such phenomena are usually explained using the properties or behavior of atoms and molecules at the submicroscopic level. To explain this, chemists symbolize the macroscopic level and submicroscopic level using chemical symbols, formulas and equations (Gabel, 1999) in Harza (2021). Although making intertextual connections between the three levels of representation is essential for chemistry learning, little is understood about whether these relationships are meaningful to learners and how teachers use intertextuality as an instructional strategy to help learners learn chemistry (Wu, 2002).

The advantages of implementing game-based learning in the classroom have been reported to result in higher learner motivation or better student achievement. Many chemistry games have been created in recent years to review and reinforce various chemistry topics (Da Silva Júnior et al., 2017), as summarized in the following Table 2.

**Table 2.** Some Educational Game Development

| Game's Name | Development Objectives |
|---|---|
| Molecular Education (Haridhi & Susanto, 2013) | Understand the constituent particles of atoms, atoms, molecules, and chemical properties |
| Educational game on the periodic system of elements and chemical bonds (Widiyaningrum, 2014) | Make it easier for students to learn the elements on the periodic table and remember the location of groups and periods. |
| Educational game "KAGAKU Game" (Arsagita, 2017) | Facilitate and motivate students in learning the periodic table material. |
| Chemistry Educational Game Basic Material of Compound Nomenclature (Haryati, 2017) | Increase student's motivation to learn chemistry and changes in student's understanding or cognitive knowledge |
| The Adventure of Thermodynamics Hero (Gutawa et al., 2018) | To reduce the negative impact of the widespread use of smartphones and help meet students' needs for material requirements in Basic Chemistry I and Physical Chemistry courses. |
| Educational game on the periodic table and elements in everyday life "Chement" (Yudha, 2018) | Simplify and maximize the process of learning Chemistry, especially on the periodic table and can explore information about examples of elements in everyday life. |
| Educational game for learning simple chemical elements and compounds (Harwanto, 2019) | Facilitate chemistry learning about chemical elements and compounds. |
| Game Edukasi level of inquiry-based laboratory work (Umah, 2019) | Increase understanding of acid-base titration practicum and minimize errors in acid-base titration experiments. |
| Educational game on atomic structure material "Atomic Hunter"(Adli, 2020) | Increase the interest and motivation of learners to learn atomic structure. |

Based on the educational game development data presented in table 2, it is expected that Chemistry teachers in secondary schools in Indonesia, especially in West Java province have implemented educational games in Chemistry learning at school. From various elaborations from the results of previous studies, it is proven that educational games are very effective in encouraging active and effective students as pedagogical tools in reconstructing student knowledge.

In addition, through educational games, multilevel representations can be included and linked. Therefore, the author feels the need to see an overview of the use of educational games in Chemistry learning in secondary schools in West Java province.

## Method

This research is a qualitative and interpretive survey to see an overview of the use of educational games in game-based chemistry learning in secondary schools in West Java province. It is qualitative because it does not involve complex statistical calculations, where the numbers (automatic calculations by Google) used in data analysis are limited to proportions or percentages — only categorical and phenomenological in nature. Phenomena in the field are interpreted based on the expertise of researchers to arrive at findings and discussions. This is relevant to survey research according to (Ponto, 2015), that survey research allows various methods to recruit participants, collecting informational data from a sample of individuals through their responses to questions.

Through random sampling technique, as many as 99 respondents who are chemistry teachers from 91 secondary schools spread across West Java province participated voluntarily in the Online Survey. Data on research subjects spread across cities or regencies in the West Java province can be seen in Figure 1.

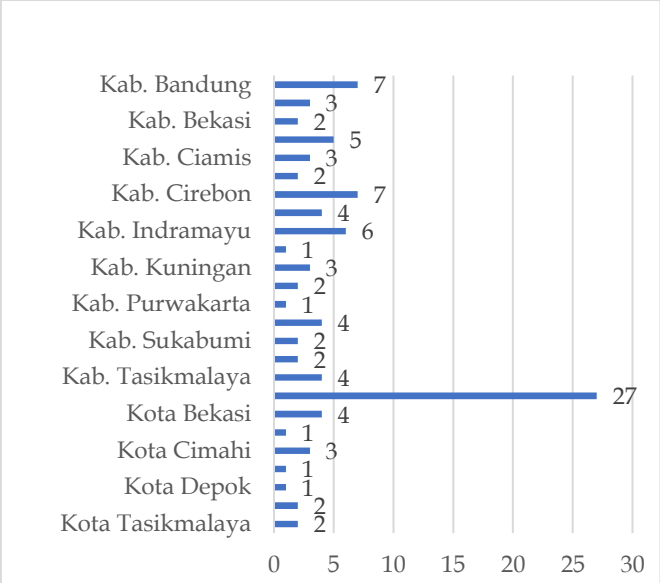


**Figure 1**. The Number of respondents in each city and regency in west java province

The research instrument used was a questionnaire on the use of educational games in game-based chemistry learning in secondary schools in West Java province which was validated by expert lecturers in the Department of Chemistry education. The questions in the survey consist of 12 questions to get an idea of the extent to which chemistry teachers know the term educational game to its application in Chemistry learning.

The data collection started from the distribution of questionnaires on Google links via WhatsApp groups to Chemistry teachers in West Java province. Teachers fill out survey questionnaires online without supervision from researchers, individually and independently. Then the collected data is then analyzed for further discussion in a comprehensive narrative to reveal the use of educational games in game-based chemistry learning in secondary schools in West Java province. Research design and method should be clearly defined.

## Result and Discussion

The first question of the survey conducted was "Have you ever heard of digital game-based learning or educational games before?" The purpose of this question is to find out whether the term digital game-based learning is still unfamiliar or not to Chemistry teachers. The survey results are shown as shown in Figure 2.

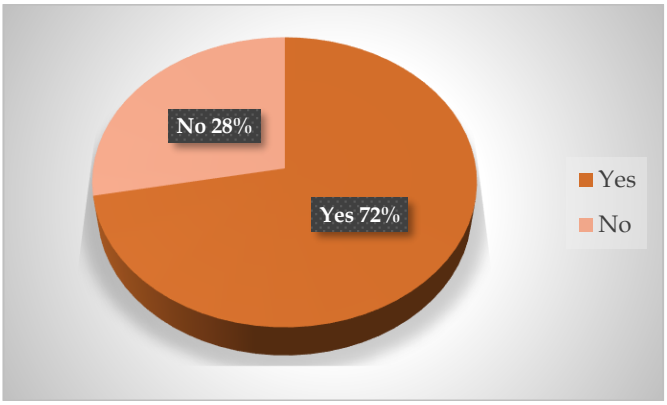


**Figure 2**. The percentage of respondents who have heard the term educational game

Of the 99 respondents, as many as 72% stated that they had heard of digital game-based learning or educational games, but the remaining 28% or a total of 28 respondents had never heard the term educational game. Insight into educational games is important for Chemistry teachers as a fun learning alternative, in addition, research has shown that game-based learning such as educational games in science is very effective in helping learners achieve learning outcomes (Petritis et al., 2022). Petritis et al. (2022) also state that games provide a nontraditional medium for learning because they can motivate learners to learn because they have fun, reinforce important concepts through repetition, and encourage continuous engagement through rewards and achievements that empower learners. Another advantage of using educational games is that learners can independently understand learning topics at their own pace, in line with the results of research conducted by Petritis et al. (2022) that game applications give learners autonomy to understand material concepts at their own pace.

The second question is "Have you ever received or received a briefing about Digital Game Based Learning?" The purpose of this question is to find out the extent to which Chemistry teachers are familiar with educational games so that they have a basis or provision in developing games in Chemistry learning as seen in Figure 3.

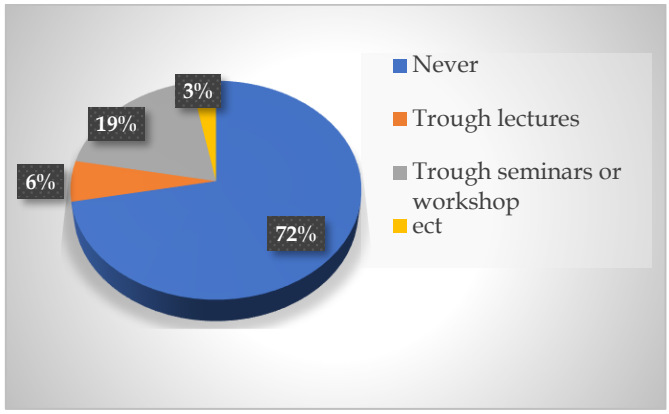


**Figure 3**. The percentage of respondents who have received educational game debriefing

From figure 3, it is shown that as many as 72% of Chemistry teachers in West Java Province have never received briefing related to educational games, and the rest have received debriefing through lectures, seminars, or workshops, through MGMP. This means that most Chemistry teachers in West Java province do not have basic knowledge about educational games and their implementation in learning. So, researchers dug further into the length of time teachers had to access games containing learning materials.

The third question is "In the last 2 years, how often have you accessed games containing learning materials?" This is questionable to get an idea of the curiosity of Chemistry teachers towards games that contain learning materials, which are expected to add variety to Chemistry learning methods in schools. The survey results are shown as shown in Figure 4.

From Figure 4, it is obtained that only a small percentage of Chemistry teachers, namely as many as 8% often access learning games, while 63% rarely and 29% have never even accessed learning games at all in the last two years. Where through games, it can be one of the solutions in learning during the Covid-19 pandemic when approximately two years, teachers and students have to experience distance learning. In addition, technology has great potential to improve the learning of learners and teachers. Knowledge of the science of learning provides guidance on the use of technology that can help learners and teachers develop

new competencies needed for the 21st century (Gupta &; Belford, 2019).

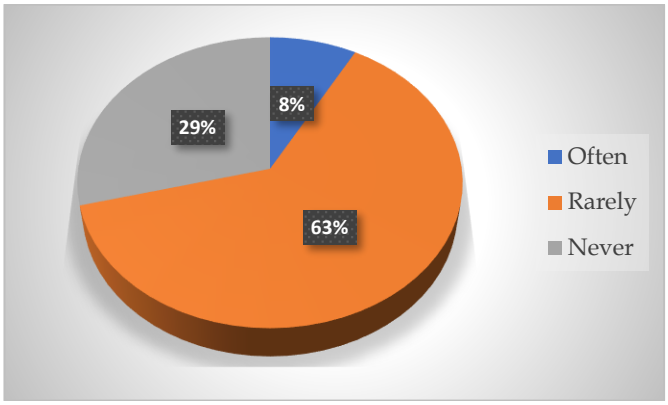


**Figure 4**. Frequency graph of time spent accessing learning games

The fourth question asked was "Are you interested in implementing Educational Games in Chemistry learning at school?" With the results as shown in Figure 5.

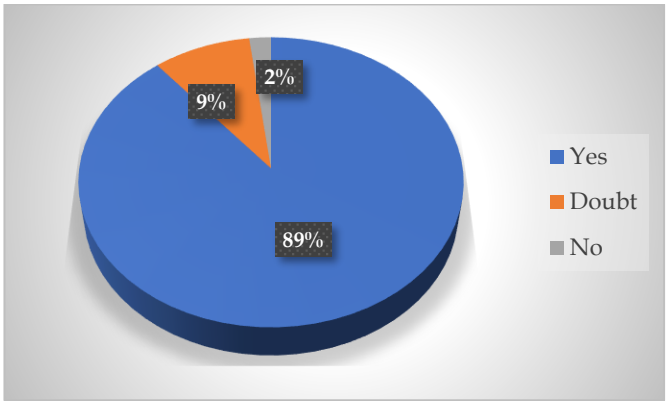


**Figure 5**. The percentage of respondents interested in implementing educational games

As many as 89% of chemistry teachers expressed interest in implementing educational games in learning. This shows that teachers are enthusiastic about game-based learning, so educational game developers are expected to create various educational games in the field of Chemistry seeing from the data that only a small percentage of teachers or around 28% have received briefings related to making educational games. That is, that teachers have an interest in implementing educational games in learning but there are limitations in making them independently.

The limitations of teachers in making educational games independently are not the main problem in this case, because teachers can use existing educational games or can develop educational games with a team of experts in the field of computerization. It is a challenge for stakeholders, or governments to provide various trainings to support the demands of using technology for efficiency and to instill 21st century skills to teachers, as explained by Gupta et al. (2019) that another problem is the amount of training needed and support available to deal with issues related to the adoption of new technologies.

The data from the previous question is relevant to the data in the results of the next question that only 35% of teachers have ever applied educational games to learning, with the distribution of data as shown in Figure 6.

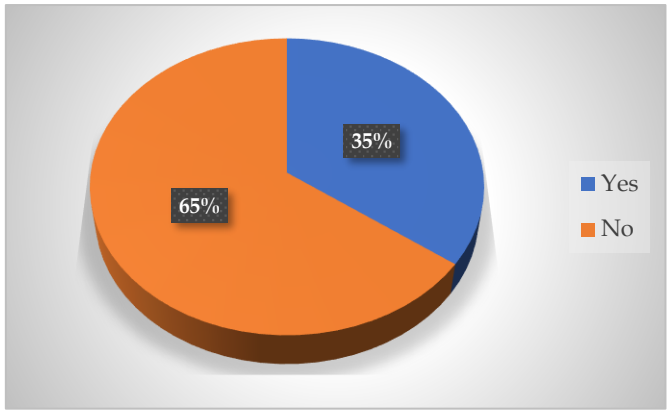


**Figure 6.** The Percentage of respondents who have applied educational games in learning

Chemical material topics that have been applied in learning based on data in Figure 6 are Periodic Systems of Elements, Electron Configuration, Molecular Geometry, Chemical Bonds, Nomenclature of Chemical Compounds, Stoichiometry, Hydrocarbons, Petroleum, Acid-base, pH of solutions and titration, Colloidal systems, Colligative Properties of Solutions, Corrosion. From the topics of the material, some games were developed by the teacher himself with the team, while others were sourced from applications on the play store, downloaded from the internet or used online, with the distribution of data as shown in Figure 7.

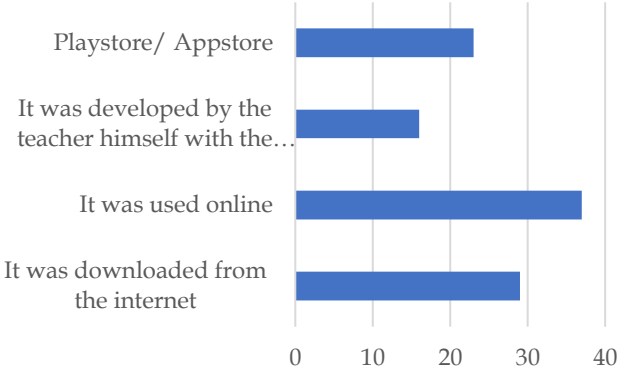


**Figure 7**. Data distribution graph of educational game sources used in learning

Applications used by teachers for game-based learning are quizizz, wordwall, periodic table games, and unreal chemist. Quizizz and wordwall applications are used primarily for assessment because teachers find it easy to make questions, there is a ranking order and questions can be timed each question. Periodic table games are used because they make learning more interesting because students can learn as well as play, which is very fun, while unreal chemists are used to see the color of the flame of metal ions in the salt, the teacher states that the color of the flame produced is good.

Based on the character of learning using game applications that have been applied by the teacher, it can be grouped into gamification and learning with the help of games as presented in Table 3.

**Table 3.** Grouping of Game-Based Learning that has been Carried Out by Chemistry Teachers in West Java Province

| | Learning Activities | Game Apps used | Material Content |
|---|---|---|---|
| Gamification | Most learning is instructional, but assessment uses game apps | *Quizizz wordwall* | Chemical Bonds Nomenclature of chemical compounds Petroleum Molecular Geometry Stoichiometry Hydrocarbons Petroleum Colloidal System Colligative Properties of Solutions |
| Game-assisted learning | Learning is designed by incorporating several game features in instructional learning | periodic *table games* *unreal chemist* | Periodic system of elements Electron configuration Acid-base, solution pH and titration |

Based on the data in table 3, no teacher has implemented full game-based learning such as the use of educational games that can construct material concepts by students independently. The form of learning is still in the form of gamification and learning with the help of games. For this reason, teachers expect the development of educational games that can visualize abstract chemical materials, thus making theoretical chemical concepts easier to learn. Included in the game can be used as an assessment instrument and provides features that make it easier for students to compile Chemistry concepts. Educational games are expected to construct chemical concepts independently to improve student's learning motivation and thinking skills in a fun way. This is in line with Gupta et al. (2019) also stating that learners prefer to use their preferred media compared to other approaches traditionally used for teaching. Thus, teachers should be willing and willing to adjust technological developments and understand the needs and interests of students in learning.

To apply educational games in learning, supporting facilities are needed in the form of digital equipment such as mobile phones, laptops, computers, or tablets. The survey results show that these facilities are already owned by each school, so it really supports the application of educational games in Chemistry learning. Problem-based learning is contained in games on mobile devices, using various ways to help learners understand concepts and solve various problems (Cahyana et al., 2017).

However, there are several obstacles experienced by teachers in implementing educational games in Chemistry learning at school, as contained in the survey results, namely unstable internet networks, limited internet quotas owned by students, skills in making media games (game applications) that support the needs of chemical content, so additional knowledge is needed in information technology, student literacy is still low, The facilities or availability of game applications are still limited and limited understanding of various game variations.

The data also shows that most secondary school chemistry teachers are interested in designing and being involved in developing educational games, with the data distributed as shown in Figure 8.

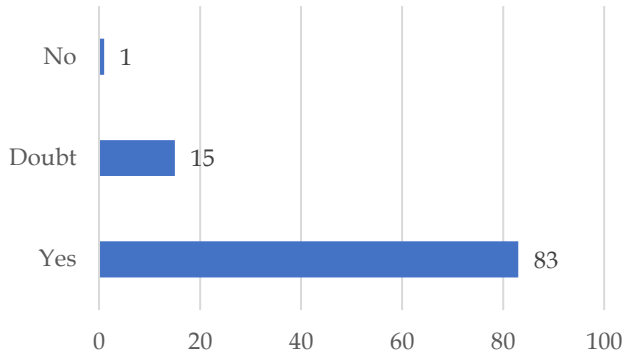


**Figure 8**. Graph of number of respondents interested in designing/developing educational games

A total of 83 respondents of Chemistry teachers stated that they were interested in designing and being involved in the development of educational games. This shows great potential to involve secondary school teachers, especially regarding Chemistry content that will be packaged in the form of educational games. Although on the one hand Chemistry teachers have limitations in terms of information technology in developing game applications, on the other hand

teachers can contribute ideas in the form of Chemistry content needed according to the character and interests of students. Research shows that seven out of eight studies that measure learners' interest report greater interest in game use than conventional learning because the main characteristics of games are fun and a source of pleasure (Garris et al., 2002).

As done by Majid et al. (2018) is by adjusting the learning method to the learning style of students on each dimension of the dominant learning style in the classroom so that students will be directed in understanding the concepts in a subject matter. While, Kusumaningrum et al. (2018) suggest the use of cartoon concepts before learning to identify learners' misconceptions and after learning to eliminate misconceptions that occur.

Therefore, an innovation has been initiated to utilize the approach of prospective teacher learners as game designers to support mastery of chemistry concepts and 21st century skills and increase student motivation in chemistry (Lay, A. &; Osman, 2018). In accordance with data from the survey that there are already teachers who receive debriefing related to educational games at the college or college level.

Game-based learning is the act of designing interactive learning activities that can gradually convey concepts and guide students towards the goal. In addition, it promotes a learner-centered learning environment where learners' interests and soft skills are developed in a dynamic and fun way (Papadimitriou, 2002). In his article Delacruz (2012) assumes that when playing educational games, player interaction with the game will motivate them and will encourage cognitive processing of game content, thereby enhancing learning. In line with this, the Chemistry teachers who participated in filling out the survey, mostly stated that the application of educational games is needed in supporting Chemistry learning in schools, with the distribution of data as shown in Figure 9.

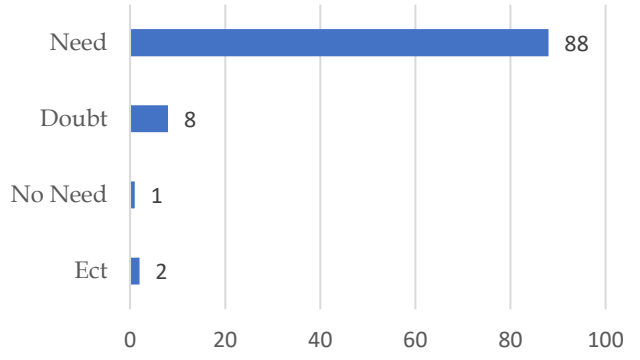


**Figure 9.** The Number of respondents who stated the need for educational games in learning

A total of 88 Chemistry teachers stated that it is necessary to apply educational games in learning on the grounds that additional media is needed to help students understand Chemistry concepts that are mostly abstract, support the visualization of abstract chemical concepts, so that learning is not too monotonous, the use of educational games is expected to increase children's motivation and learning outcomes towards chemistry learning. In addition, educational games facilitate the learning styles of students who are already dependent on devices and games, increase teacher creativity in providing chemistry learning, games are expected to provide a more pleasant chemistry learning atmosphere for students, to enrich educator's strategies so that students have an interest in learning, due to the demands of the digital era, making innovations and works that make teachers more active, independent and professional, To make learning more effective and efficient, train students' abilities in 21st century skills, and provide stimulus for students and adjust the conditions of the digital generation.

The reasons given by the teachers are very much in line with those presented (Papadimitriou, 2002), that the educational benefits of game-based learning are particularly evident in subjects where learners report greater attention, and it can be shown that increased levels of pleasure are positively correlated with increased deep learning and higher-order thinking. Meanwhile, (Plass et al., 2020) explained several roles of game-based learning such as preparing for future learning, intended to provide learners with shared experiences that can be used for further learning activities, such as class discussions or problem-solving activities outside games; learning new knowledge and skills for learners to acquire as part of the game; practice and strengthen existing knowledge and skills, assuming that basic knowledge or skills already exist, and providing opportunities either to deepen this knowledge by applying it to problems in different contexts and with different features, or to automate skills by applying them repeatedly; build learning and innovation skills, by developing socio-emotional skills of greater complexity related to teamwork, collaboration, problem-solving, creativity.

The peculiarity of chemistry learning that is one of the problems for students is the ability to understand the relationship between real life and molecular aspects (Rastegarpour dan Marashi, 2012). Students have difficulty understanding chemistry subjects in the learning process without visualization of molecular aspects or real-life examples. The role of educational games is to visualize molecular aspects in chemistry subjects. Plass et al. (2015) states that the uniqueness of learning with educational games can be found by focusing on how the learning environment in games is

designed. So, all types of materials can be used in the form of educational games. Further in the article, Salame et al. (2022) states that appropriate future studies are needed which involve modifying instructional approaches to constructivist and collaborative approaches.

## Conclusion

As many as 35% of chemistry teachers in West Java province have included game applications in Chemistry learning instructional, namely in the form of gamification and learning using game assistance. And 65% of teachers have never used games in learning due to lack of knowledge about the variety of educational games, lack of skills in developing educational games independently. Thus, from the results of this study, it was obtained that game-based learning has never been applied in Chemistry learning in secondary schools in West Java province.

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**Authors Contributions**

Conceptualization: S.F.T., and W.; methodology: S.F.T. and W.; validation: W.; investigation: S.F.T.; resources: S.F.T.; formal analysis: S.F.T.; data curation: S.F.T.; writing—review and editing: S.F.T. and W.; supervision: W. All authors have read and agreed to the published version of the manuscript.

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**Conflicts of Interest**

The author declares that there is no conflict of interest in this research.

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