ChemVirtual Lab: Gamified Learning Experience on Reaction Rate Topic to Improve Learning Outcomes

Retno Indah Rokhmawati*1, Tuffahati Sholihah 2, Kumara Sahasika Laksmana 3, Rizky Pramudita 4, Ibrahim Sambata Sarborn 5, Adam Hendra Brata 6

1,2,3,4,5,6 Brawijaya University, Malang
1 retnoindahr@ub.ac.id, 2 tuffahati393@student.ub.ac.id, 3 kumara@student.ub.ac.id, 4 rizkypramudita@student.ub.ac.id, 5 ibrahimsambata@student.ub.ac.id, 6 adam@ub.ac.id
*Corresponding Author

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Abstract. This study aims to improve student learning outcomes through gamification of chemical learning media. As we know that chemical material, especially reaction rates, is abstract in nature, so it is quite difficult to convey this concept to students. Because the measured compounds vary greatly in terms of concentration, this material has complex features. However, in real conditions, students have limited access to chemical laboratory equipment, so learning media is needed that considers aspects of people, problems, and context to provide learning experiences like real laboratories. ChemVirtual Lab is a learning tool that combines immersive learning experiences with game elements to improve students' learning outcome by allowing them to direct their own learning and inspiring them to think creatively and innovatively. The primary model in this study is the ASSURE learning media development paradigm. Evaluation of the usage of educational media was conducted to ascertain factors of satisfaction and usefulness with 3 media experts and 3 material experts. According to the six experts' test results, it would be possible to implement the media. Then the media was implemented to 62 high school students who were studying Rate of Reaction material. The Paired Sample T-Test was used to examine the effectiveness of the media's implementation, and the results revealed significant differences in learning outcomes as well as a tendency for post-test scores to rise above pre-test results.

Keywords: Gamified Learning, Virtual Chemistry Lab, Creative Thinking, Immersive Learning, Student Agency

1 Introduction

A scientific field called chemistry contains knowledge, facts, hypotheses, principles, laws, research findings, and procedures. The abstract nature of chemistry frequently hinders students' ability to learn concepts in chemistry classes. Abstract concepts might be challenging for many students to understand. Reaction rate material, according to Kirik and Yezdan [1], is one of the abstract chemical notions that makes it difficult for high school students to comprehend. According to the findings of the interviews and initial observations our team made at Brawijaya Smart School, one of the chemistry teachers said that the material on chemical reaction rates is material that can be categorized as moderate to easy, but it is abstract in nature and needs more understanding, so that the students have to appropriately create a
knowledge of the fundamental ideas of the subject. As a result, laboratory exercises are a crucial part of learning chemistry since they let students develop their own understanding. As we know that chemical material, especially reaction rates, is abstract in nature, so it is quite difficult to convey this concept to students. Therefore, this research aims to improve student learning outcomes through gamification of chemical learning media.

Additionally, laboratory learning techniques can raise students’ engagement levels and sense of agency. However, in practice, the importance of laboratory application for learning chemistry is underappreciated. According to several studies, many science laboratories continue to fall short of the infrastructure and facility requirements set forth in Regulation of the Minister of National Education No.40 of 2008[2]. Additional issues include the inadequate facilities, the usage of lab time, and the lack of practicum tools. Some of these issues present potential for the creation of interactive learning materials, one of which is gamification of the classroom.

Gamification, which is described as "the use of game design elements in non-game contexts," has attracted more and more attention in recent years in educational research. Because of its implications for education, gamification is a promising approach for classroom settings. At all stages of education, from elementary schools to higher institutions, the application of gamification in the classroom has been shown to increase learning outcomes and student engagement[3]. Gamification is able to stimulate students’ creative thinking skills. In a gamification activity, students are given the freedom to explore and try approaches to solving a given problem. This encourages students to think creatively to become alternative solutions and develop their experimental abilities. Creative thinking skills are one of the high-level skills needed by students to solve problems, both in learning and in daily life. These skills should be honed and developed in classroom learning. Especially in practical subjects, such as chemistry.

Based on the aforementioned description of the issue, the researcher developed an interactive learning materials that implement gamification elements to simplify the process of learning chemistry. The development of this media called ChemVirtual Lab promotes hands-on instruction in reaction rate chemistry[4]. The ASSURE instructional model served as inspiration for the creation of Chemvirtual Lab. Because this model is created to provide a systematic method in developing effective and efficient learning by considering the needs, student preferences, and student characteristics. The ASSURE model can be adapted by incorporating technology and media, in this case study using a gamification approach, to enable students to be actively involved in learning. This gives the model a great degree of flexibility. In order to generate immersive learning experiences, this model is focused on the use of media and technology in the development of learning processes and activities[5].

The development of ChemVirtual Lab aims to give students the freedom to construct their own knowledge because it supports them in selecting a learning path that matches their preferences. For instance, students can select the Lab feature (playground representation) before the Career feature (representation of cognitive questions). ChemVirtual Lab empowers students to exercise their freedom to think creatively and to act independently. ChemVirtual Lab will be a way to offer a different learning setting that can work synergizely with offline learning in the classroom, making learning more significant and student-centered. In this study the focus is on proving whether this gamification-based learning media can improve student learning outcomes. Aspects of creative thinking and student agency are potential factors that can be observed at this time, but can be measured in future
studies because they require data on media use over a period of more than one month and intensive frequency of use.

2 Literature Review

2.1 Gamification in Learning Media

Gamification is the use of game metaphors, gaming concepts, and game features in contexts outside of the actual game to boost user engagement and motivation as well as affect user behavior [6]. Users of game mechanics are 40% more likely to master new abilities. The gamification technique raises students' motivation and engagement levels for the tasks and procedures they are taking part in [1][7].

The primary issue in contemporary education is the lack of motivation and engagement on the side of students to actively engage in the learning process, which affects learning outcomes, particularly for learning that is precise in nature, like chemistry[8]. As a result, instructors try to employ novel strategies and techniques to engage students and encourage them to take part in the training. Rewarding effort and results is one approach that may be used to boost motivation for participation and physical activity [3]. Therefore, gamification's existence in the educational setting is a beneficial answer and aids in resolving the issue of student retention, participation, and motivation levels.

2.2 Creative Thinking and Student Agency

Creative problem-solving abilities and developing a sense of student agency are some of the qualities that will be in need in 2025 [9]. The ability to think creatively may always be developed, learnt, and trained. Based on this, the capacity for creative thought stresses behavioristic changes as a result of the learning activities that have been undertaken, in addition to conceptual mastery [10]. One of the high-level talents that students need to address challenges in both their academic and daily lives is the ability to think creatively. These abilities ought to be refined and developed in the classroom, especially in disciplines that are practical, like chemistry.

A supportive learning environment and engaging learning resources are necessary for the development of these skills [11].

Student agency is a skill that may be acquired either individually or in groups and is based on interactions with other people, things, and concepts in the context of specific social-structural and relational acts [9][7]. Student agency refers to a person's capability to actively take charge of their own life and the environment around them, to make decisions, set objectives, engage in self-reflection, and act responsibly to effect change. Student Agency enables learners to take charge of their education, empowering them to make decisions about their education, establish personal goals, and actively participate in learning activities [12][13]. The ability to self-regulate, be self-aware of one's strengths and flaws, and take initiative to accomplish goals are all traits of students who have agency skills. Student agency abilities assist individuals in acquiring the independence required for success in their personal, academic, and professional life.

3 Methodology

Gamification is a technique that applies game elements to other fields, including education. The game elements in question are badges, competition, rewards,
levels, leaderboards, progress bars, and Experience Points (EXP). However, in the context of developing instructional media, instructional designs are needed to direct students in learning. In this research, the instructional design applied is ASSURE because the stages are aligned with game development phase which analyzes student learning conditions, learning objectives, to the selection of the type of media and material displayed. So that the substance of learning is still delivered in an attractive and interactive way.

The ASSURE instructional model is used in this study as a framework of learning media development. The words ASSURE stand for Analyze Learners, States Standards and Objectives, Select Strategies, Technology, Media, and Materials, Utilize Technology, Media, and Materials, Require Learner Participation, and Evaluate and Revise (see Figure 1. ASSURE Model).

The needs of the two high schools (private and public) in Malang City are first investigated in this study. During the Analyze Learners phase, we interviewed senior chemistry teachers from each high school in-depth. We discovered that these teachers had difficulties visualizing the reaction rate process, which is a fundamental aspect of chemistry curriculum presented as abstract concepts. Based on these issues, it has been determined that the emphasis is on the requirement for personal learning media that students may access via their smartphones and that the media uses gamification to foster a competitive environment in the classroom. Both of teachers determine the broad and detailed educational objectives that should be met by students. The goal is for students to be able to summarize and present experimental findings in the chemistry lab by using collision theory to explain the variables that affect reaction rates. As a result, researchers developed the ChemVirtual Lab as a learning media. Two classes (a total of 62 students) from two representative high schools were recruited to test this learning resource while they were studying Reaction Rate. Because the data is normally distributed (parametric), the test results compare the outcomes of the pre-test and post-test using the Paired Sample T-Test.

4 Framework for Designing and Discussion

The ASSURE framework is used in this study to describe how learning media are developed. ASSURE is deemed suitable since it focuses on essential components that are the main objectives of this case study. The design of media must take into consideration the overall characteristics of students, planned competencies, and the
types and ways of student participation in usage of media, among other crucial considerations. Following are descriptions of each development stage's result.

4.1 Analyze

The first iteration of the design of the ChemVirtual Lab application entails conducting interviews and early observations with senior teachers from two high schools in Malang City, in order to ascertain the first needs and definitions of student needs as well as the necessity of prioritizing the content for Reaction Rate topic. Then, based on experiments and further interviews, we discovered that students had conceptual mistakes during the process of understanding chemical reaction rates because of the concepts' abstraction and difficulty. This had a significant impact on lowering students' desire and motivation to study chemistry in greater depth. The requirement for mobile simulation learning media of a chemical lab was also noted during this interview.

4.2 State Standards and Objectives

The subsequent procedure involves identifying and analyzing the learning objectives to be attained by the ChemVirtual Lab on the topic of chemical reaction rates based on the existing curriculum. According to the curriculum, students should be able to summarize and present their lab-based experimental results in chemistry by utilizing collision theory to explain the factors that influence reaction rates.

4.3 Select Media and Materials

At this point, the researchers created a requirement statement using the data from the interviews and classroom observations. This data are then processed to create a problem statement that refers to the selection of ideas and concepts for the ChemVirtual Lab application's learning materials, the development of features based on students' needs and characteristics, and the choice of colors and other gamification components.

4.4 Utilize Media and Materials

The use of technology, media, and materials as resources to aid in the learning process is part of this stage. With an emphasis on Android users running the newest version of Nougat, researchers created ChemVirtual Lab utilizing the Unity cross-platform game engine. Researchers also modified the gamification approach in ChemVirtual Lab to boost student engagement and encourage the growth of students' critical-thinking abilities.

The ChemVirtual Lab application is designed with a range of interactive tasks requiring for active engagement from students, such as simulations of lab features, game aspects to earn badges, coins and XP, leveled questions, and other missions. The user will be taken to the Homepage, which is the primary page, after logging in. Basic information on the home page includes the username, experience points, level acquired, user skin, and badges. Additionally, it has available subfeatures for students, including labs and careers (see Figure 2).
4.5 Require Learner Participation

The researcher at this point specifically highlighted the requirements for student involvement in using the ChemVirtual Lab (see Figure 3 right side). Students can conduct experiments in the lab feature on variables that affect reaction rates to better understand how these variables can boost reaction rates. Without the need for lab supplies, this feature serves as a virtual chemistry lab that makes it easier for teachers to explain the idea of reaction rates. This feature is a great addition to the program since it gives students the opportunity to research and build their understanding of the reaction rate content. It also seeks to provide students a sense of learning freedom.

In addition, the Career feature provides an example for the depth of student understanding of the material reaction rate by evaluating student understanding and providing feedback (see Figure 3 left side). Students are asked questions about the factors that affect the rate of reaction in this feature so that they can recall what they have learned in the Lab feature. According on degree of complexity, the career feature is split into two categories: beginners and masters. Levels 1 through 4 are for beginner categories, and levels 5 and 6 are for master categories. After answering the questions, students will receive corrections from answers that will allow them to determine whether the provided answers are right or wrong. If students answer correctly, they will receive feedback in the form of coins and XP; however, if they respond incorrectly, they will receive feedback in the kind of tips to help remind them of the information they need to know to solve the problem.

The Skin Shop and Leaderboard features, which are gamification components, are applied in this media to boost student learning motivation (see Figure 4 left side). Students can purchase skins in the skin shop feature using the cash they earn from their careers. Students receive extra coins if they successfully complete each level in the career.
This function is one of the applicable gamification aspects, and with appealing visualization it can help boost student engagement with the information so that students are driven to continue the course. The Leaderboard feature offers data on gamification components like badges, levels, leaderboards, virtual currency, experience points, and awards that students have earned so that students can determine their learning process's strengths and weaknesses (see Figure 4 right side). Students can also share their profiles for reports to teachers or parents.

4.6 Evaluate and Revise

The evaluation procedure is divided into two stages: first, evaluation by media and material experts; second, testing with real users (high school students who study reaction rates). During the evaluation phase, a validation test with experts is conducted to determine the viability of its implementation in the field. At this point, direct trials of
the ChemVirtual Lab application's final prototype are used in conjunction with open expert interviews to test the validity of the program. The test findings are presented as assessments that may be quantified using a questionnaire testing approach. The questionnaire used for the test was created by adapting surveys from media experts and subject matter experts as well as the Learning Experience Questionnaire (LEQ). The test results from three learning experts and three media experts indicated that the outcomes could potentially be used with a number of improvements, as listed in Table I. In general, the application has been able to run without issue, and the content of the learning media has been presented in an appropriate way. Improvements must be made to the instruction manual so that the application may be used independently without supervision. On smartphones running Android platform version 7 (Nougat), it generally functions normally, however there are compatibility and dependency concerns throughout the installation and registration process.

<table>
<thead>
<tr>
<th>Experts</th>
<th>Evaluation Score</th>
</tr>
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<tbody>
<tr>
<td>Media Expert 1</td>
<td>0.819549</td>
</tr>
<tr>
<td>Media Expert 2</td>
<td>0.842105</td>
</tr>
<tr>
<td>Media Expert 3</td>
<td>0.736842</td>
</tr>
<tr>
<td>Learning Expert 1</td>
<td>0.842105</td>
</tr>
<tr>
<td>Learning Expert 2</td>
<td>0.902256</td>
</tr>
<tr>
<td>Learning Expert 2</td>
<td>0.834586</td>
</tr>
</tbody>
</table>

**Mean** 0.82957 (valid with some revisions)

The evaluation continued with testing involving high school students. The test context was carried out in the learning process in the chemistry class by involving 62 students representing representatives of the two high schools who had been involved at the beginning of the study. Before using ChemVirtual Lab, students receive introductory material about reaction rates. In the following week, students are given assignments to explore the features of ChemVirtual Lab according to each student's ability and pace. Students are directed to compete so that their names appear on the Leaderboard. The following week the students were given a post-test related to the reaction rate material. The results of the pre-test and post-test represent student learning outcomes within 3 weeks. Then the results of the split were tested for normality with the One Sample Kolmogorov-Smirnov Test technique. The test results show an average increase seen from the mean pre-test = 70.90 and post-test = 81.00.

The significant value of Asymp.Sig (2 tailed) is known to be 0.703 for the pre-test and 0.693 for the post-test based on Table II of the following PSPP report. The two data can therefore be said to be regularly distributed based on the Kolmogorov-Smirnov test's method. As a result, the Paired Sample T-Test's normalcy assumptions or conditions have been fulfilled.

In this research, the hypothesis is set as follows.
- **H0** = There is no difference in students' pre-test and post-test learning outcomes when using ChemVirtual Lab on the topic of Reaction Rate in class
- **H1** = There are differences in students' pre-test and post-test learning outcomes when using ChemVirtual Lab on the topic of Reaction Rate in class
Table 2. Result of One Sample Kolmogorov-Smirnov Test

<table>
<thead>
<tr>
<th></th>
<th>Pre-Test</th>
<th>Post-Test</th>
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<tbody>
<tr>
<td>N</td>
<td>62</td>
<td>62</td>
</tr>
<tr>
<td>Normal Parameters</td>
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<td></td>
</tr>
<tr>
<td>Mean</td>
<td>70.90</td>
<td>81.00</td>
</tr>
<tr>
<td>Std. Deviation</td>
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<td>6.85</td>
</tr>
<tr>
<td>Absolute</td>
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<td>.09</td>
</tr>
<tr>
<td>Most Extreme Differences</td>
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<td></td>
</tr>
<tr>
<td>Positive</td>
<td>.07</td>
<td>.09</td>
</tr>
<tr>
<td>Negative</td>
<td>-.09</td>
<td>-.09</td>
</tr>
<tr>
<td>Kolmogorov-Smirnov Z</td>
<td>.71</td>
<td>.71</td>
</tr>
<tr>
<td>Asymp.Sig.(2-tailed)</td>
<td>.703</td>
<td>.693</td>
</tr>
</tbody>
</table>

Based on Table III as a PSPP output, it is known that the value of Sig. (2. tailed) of 0.00 <0.05, then H0 is rejected and H1 is accepted. So it can be concluded that there are differences in students' pre-test and post-test learning outcomes when using ChemVirtual Lab on the topic of Reaction Rate in class. In addition, it is known that the calculated t value is negative (t = -18.46) because the pre-test value is lower than the post-test result. In this context, a negative t-value can have a positive meaning because it indicates an increase.

Table 3. Paired Samples T-test

<table>
<thead>
<tr>
<th>Output</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
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</tr>
<tr>
<td>Std. Deviation</td>
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<tr>
<td>S.E. Mean</td>
<td>0.55</td>
</tr>
<tr>
<td>t</td>
<td>-18.46</td>
</tr>
<tr>
<td>df</td>
<td>61</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>0.000</td>
</tr>
</tbody>
</table>

ChemVirtual Lab's development and implementation have led researchers to the conclusion that they may implement an instructional model that is appropriate for the case study to develop learning media that impact or boost learning outcomes. In this case study, the preliminary analysis demonstrates that instruction requires media that can convey a true atmosphere for learning and digital representation of the chemistry lab. In order to build effective learning media, it is crucial to comprehend the needs and preferences of students. Furthermore, in order to decide which priority competences will be supported by learning media, researchers and teachers must work together. This is important because the development of media and content requires a large amount of time and effort, so it is necessary to prioritize development.

In order for the media to be used right away after it has been developed, researchers and teachers must also agree on the sorts of media and gadgets that students already own. The media must be verified by media and material experts prior to implementation in order to assure their eligibility. It's critical to encourage student participation [14]. Students in this study received pre-test preparation materials, missions and exploration opportunities, and the study concluded with a post-test and reflection. This series is excellent for delivering a thorough influence on student learning, rather than merely as a research subject.

5 Conclusion

The results of this study indicate that investigating student needs and features through the participation of teachers who are actively engaged in the teaching process...
will be highly helpful for media researchers or developers in obtaining an accurate representation of a learning condition. Other crucial requirements, such immersive learning experiences that can be used in media with gamification aspects, can also be defined by researchers. Students' ability to choose their own pace of learning can foster innovative thinking and develop their sense of autonomy [15]. The word "agency" connotes a sense of obligation to engage with the world and, in doing so, improve the conditions of people, events, and circumstances. The capacity to define a guiding purpose and specify activities to accomplish a goal is a requirement for agency [16].

References
15. S. H. Dewi, S. Sudarmin, S. Haryani, dan ..., “Laboratory Course During Pandemic Covid-