Journal of Chemical Learning Innovation
Vol. 1, No. 2, December 2024, pp. 68~74
ISSN: 3063-0886, DOI:10.37251/jocli.v1i2.2997

The Use of Flash Media as an Innovation in Chemistry Learning to Improve Student Learning Achievement in Atomic Structure Material

I Made Krisna Budi[1], and Ni Nyoman Nuryani[2]
[1]Department of Chemistry Education, University of Mataram, West Nusa Tenggara, Indonesia
[2]State Senior High School 2 Mataram, West Nusa Tenggara, Indonesia

Article Info

Article history:

Received Sep 27, 2024
Revised Oct 17, 2024
Accepted Nov 25, 2024
OnlineFirst Dec 30, 2024

Keywords:

Atomic Structure
Chemistry Learning
Flash Learning Media
Interactive Multimedia
Learning Achievement

ABSTRACT

Purpose of the study: This study aims to determine the effect of using Flash-based learning media on students' learning achievement in chemistry, specifically on the topic of atomic structure, compared to conventional teaching methods.

Methodology: This study employed a quasi-experimental design using a pretest-posttest control group design. The instrument used was a multiple-choice test consisting of 20 items. Data were collected through pretest and posttest. Data analysis included validity and reliability testing, homogeneity test using F-test, and hypothesis testing using t-test with pooled variance.

Main Findings: The results showed that students taught using Flash media achieved higher learning outcomes compared to those taught using conventional methods. The experimental group demonstrated better average scores and higher classical completeness. Statistical analysis indicated a significant difference between both groups, confirming that Flash media positively affects students' achievement in atomic structure learning.

Novelty/Originality of this study: This study introduces the application of specifically designed Flash media for atomic structure learning, integrating interactive animation and conceptual visualization. It provides empirical evidence of its effectiveness, offering a more focused approach compared to previous general multimedia studies and contributing to innovation in chemistry learning media development.

Corresponding Author:
I Made Krisna Budi,
Department of Chemistry Education, Universitas Matara, Majapahit Street No. 62, Dasan Agung Village, Selaparang District, Mataram City, West Nusa Tenggara, Indonesia
Email: ikrsnabdmadee@gmail.com

1. INTRODUCTION

Chemistry learning is a field of study that demands an understanding of abstract concepts and higher-order thinking skills [1], [2]. Many concepts in chemistry, particularly atomic structure, cannot be directly observed, making them often difficult for students to grasp [3], [4]. This impacts student interest in learning and achievement in chemistry [5], [6]. Teachers are required to present material in an engaging and understandable manner. Therefore, learning innovations are needed that can bridge abstract concepts into more concrete ones.

Atomic structure, as a fundamental material in chemistry, plays a crucial role in understanding more advanced concepts [7], [8]. However, many students struggle to understand the structure of subatomic particles and electron configurations. Learning methods that are still dominated by conventional methods tend to lead to students being passive and less actively engaged [9], [10]. This condition results in low student learning outcomes in this material. Therefore, a more interactive and technology-based learning approach is needed [11], [12].

Developments in information technology offer significant opportunities to improve the quality of learning [13], [14]. One innovation that can be implemented is the use of multimedia-based learning media such as Flash [15], [16]. Flash media can present engaging animations, visualizations, and interactions that can help students grasp abstract concepts [17], [18]. The use of this media can also increase student motivation and attention in learning. Thus, Flash media has the potential to be a solution for effective chemistry learning.

Flash media has the advantage of displaying simulations of microscopic processes that cannot be directly observed. The visualizations presented can help students develop a better conceptual understanding [19], [20]. Furthermore, the interactive features in Flash media enable students to learn independently and exploratively [21], [22]. This aligns with modern learning principles that emphasize student-centered learning [23], [24]. Therefore, the use of Flash media in chemistry instruction warrants further study.

Several previous studies have shown that the use of multimedia-based media can improve student learning outcomes [25], [26]. However, most of these studies have focused on general media use and have not specifically examined the effectiveness of Flash media on atomic structure. Furthermore, research that optimally integrates interactivity and visualization is still limited. This situation indicates a research gap that requires further study. Therefore, research that specifically examines the effect of Flash media on student achievement in atomic structure is needed.

The novelty of this research lies in the use of Flash media, specifically designed to visualize atomic structure concepts interactively and systematically. This media not only presents information but also engages students in the learning process through animation features and interactive exercises [27], [28]. Furthermore, this study directly examines the effect of this media use on student achievement. This approach is expected to provide new contributions to the development of chemistry learning media. Thus, this research has added value compared to previous studies.

The urgency of this research is based on the need to improve the quality of chemistry learning in schools. Low student achievement in atomic structure is a problem that needs to be addressed immediately. The use of innovative learning media is expected to be an effective solution to improve student understanding. Furthermore, this research also supports the use of technology in education in accordance with the demands of the digital era. Therefore, this research is crucial to provide alternative, more effective and innovative learning strategies.

2. RESEARCH METHOD

2.1. Type of Research

This study employed a quasi-experimental design because the subjects were not randomly assigned but were placed in naturally formed groups, such as students in a single class [29], [30]. This design was chosen because field conditions did not permit regrouping of the subjects. A pretest-posttest control group design was employed in this study. The pretest was administered to measure students' initial abilities before the treatment was administered. Meanwhile, the posttest was used to determine students' abilities after receiving the treatment. If the pretest results indicate a difference in initial abilities between the two groups, then hypothesis analysis is conducted based on the difference in scores (gain). However, if there is no significant difference in initial abilities, then hypothesis testing can be carried out directly using posttest scores. Thus, this research design allows researchers to evaluate the effects of the treatment more accurately. The research design used is as follows:

Table 1. Research Design

Class	Pretest	Use of Flash Media	Posttest
Experiment	Yes	Yes	Yes
Control	Yes	No	Yes

2.2. Research Population and Sample

The population is the entire subject targeted in a study. In this study, the population includes all tenth-grade students consisting of classes X1, X2, X3, X4, and X5 at Mataram 2 State Senior High School. This population was selected because it has characteristics that match the research objectives. In addition, all classes are at the same level, allowing for comparisons. Thus, this study population has a fairly good level of uniformity. The sample is a portion of the population that is used as the object of research and is considered to be representative of the entire population [31], [32]. The sampling technique in this study was carried out by lottery because the subjects have been divided into natural groups in the form of classes. The research sample consisted of two classes, namely one class as the experimental group and one class as the control group. Based on the lottery results, class X2 was designated as the experimental class, while class X3 was designated as the control class. Each class consisted of 42 students, resulting in a total sample of 84 students. This number is considered representative because it covers approximately 40% of the total population of tenth-grade students at Mataram 2 State Senior High School. With this number, the sample is considered sufficient to represent the population as a whole.

2.3. Data Collection Instruments and Techniques

The instrument used in this study was an objective multiple-choice test [33], [34]. This test consists of two main parts: the stem, which represents the question statement, and the options, which represent alternative answers. Each question item has five answer choices: A, B, C, D, and E. Of these five, only one answer is correct, while the other options serve as distractors. Scoring was done by assigning a value of 1 for a correct answer and 0 for an incorrect answer. The instrument used in this study was systematically designed through the preparation of a question outline. In addition, the instrument was also pre-tested to ensure its validity and reliability before being used in the study. The outline of this research instrument can be seen in Table 2.

Table 2. Research Instrument Grid

Learning materials	Indicator	Question Number	Amount
The development of atomic theory from Dalton's atomic theory to modern atomic theory	Explain the development of atomic theory from Dalton's atomic theory to the modern atom.	1,3	2
	Explain the constituent particles of atoms (protons, neutrons, and electrons).	2,4	2
Atomic structure	Determine the number of protons, neutrons, and protons based on mass number.	7, 8, 11, 12, 14, 15	6
	Classify elements into isotopes, isotones, and isobars based on atomic number and mass number.	5, 6	2
	Determine electron configuration and relative atomic mass.	9, 10, 13, 16, 17, 18, 19, 20	8
	Amount		20

The data collection process is a crucial stage in any research because it determines the quality of the results obtained. The data collected in this study consisted of several types according to the analysis needs. The first data was the results of a pretest, which was used to determine students' initial abilities regarding atomic structure before treatment was given [35], [36]. Next, data regarding student achievement in atomic structure was obtained through testing techniques. The test instrument used had undergone validity and reliability testing, thus ensuring its suitability for use in research. Thus, the data obtained was expected to be accurate and objectively reflect students' abilities.

2.4. Data Analysis Techniques

Before conducting further data analysis, it is first necessary to test whether the obtained data have homogeneous variance. A homogeneity test is performed using pretest data to ensure equality of variance between the groups being compared. Homogeneity of variance is tested using the F-test, comparing the largest variance with the smallest variance [37]. The variance for each group is calculated based on student scores, averages, and sample size. The test criteria are: if the calculated F-value is less than the F-table, then the data variance is considered homogeneous. Conversely, if the calculated F-value is greater than the F-table, then the data variance is considered non-homogeneous. The results of this test serve as the basis for determining the subsequent analysis techniques to be used in hypothesis testing.

To test the research hypothesis, a difference test, namely the t-test, is used. In this test, there are two approaches: separated variance and pooled variance. The choice of t-test formula is adjusted according to the sample size and the results of the homogeneity of variance test. The separated variance formula is used in several situations: when the sample size is the same but the variance is homogeneous, when the sample size is the same but the variance is not homogeneous, and when the sample size is different but the variance is not homogeneous [38]. The degrees of freedom used in the calculation are adjusted accordingly. Meanwhile, the pooled variance formula is used when the variances of the two groups are homogeneous, whether the sample sizes are the same or different. After the calculated t value is obtained, it is then compared with the t table value at a 5% significance level. If the calculated t value is less than or equal to the t table, the alternative hypothesis is rejected. Conversely, if the calculated t value is greater than the t table, the alternative hypothesis is accepted. Thus, the t test results are used to determine whether or not the treatment effect is present in the study.

3. RESULTS AND DISCUSSION

3.1. Student Learning Achievement Data

Student learning achievement data was obtained from the results of the final test conducted at the end of the learning process. The final test was given to two classes, namely class X2 as the experimental class and class X3 as the control class. The results obtained showed that in the experimental class, student scores were in the range of 45 to 100 with an average score of 78.05. Meanwhile, in the control class, the range of scores obtained was 30 to 95 with an average score of 68.69. The minimum completion criteria set for atomic structure material is 70. Based on these criteria, the classical learning completion level was obtained in each class. The experimental class showed a classical completion level of 80.95 percent, while the control class reached 64.29 percent. Thus, there is a difference in learning achievement between the two classes. A summary of the student learning achievement data is presented in Table 3.

Table 3. Student Learning Achievement

Aspects	Experimental Class	Control Class
Number of students	41	42
Highest score	100	95
Lowest score	45	30
Average score	78.05	68.69
Classical completion	80.95%	64.29%

3.2. Results of the Homogeneity of Variance Test

The homogeneity of variance between the experimental and control classes was tested using the F-test. The data used in this test included the pre-test and post-test data, as the data must meet the homogeneity of variance requirement before conducting a difference test. This test aims to ensure that both groups have equal variances so that they can be compared accurately. Based on the calculations on the pre-test data, the experimental class had the largest variance of 187, while the control class had the smallest variance of 143.4. The calculated F-value was 1.304. Meanwhile, the F-table value at the 5 percent significance level with 40 degrees of freedom in the numerator and 41 in the denominator was 1.69. Because the calculated F-value was smaller than the F-table value, it can be concluded that the variances of the two groups were homogeneous.

This homogeneity test on the pre-test data was then used as the basis for conducting a difference test to determine students' initial abilities in atomic structure. Furthermore, a homogeneity test was also conducted on the post-test data to ensure the suitability of further analysis. In the final test data, the experimental class variance was 297.33 and the control class variance was 190.32. The calculated F value obtained was 1.56, while the F table value remained at 1.69 at the same significance level. These results indicate that the calculated F value is smaller than the F table, so the variance of the two groups is also declared homogeneous. By fulfilling the requirements for homogeneity of variance in both types of data, the analysis can be continued with a difference test. This test aims to determine the effect of the use of learning media on student learning achievement.

3.3. Hypothesis Test Results

Based on the results of the homogeneity test on the initial test data, the data were then analyzed using a difference test. The type of test used was a t-test with a pooled variance approach because the F-test results showed that the variances of both groups were homogeneous. The results of the analysis showed that the calculated t-value was 0.25, while the t-table value was 1.99. Because the calculated t-value was smaller than the t-table, it can be concluded that both groups had equal initial abilities in the atomic structure material before being given treatment. Furthermore, the final test data that had met the homogeneity requirements were also analyzed using a t-test with a pooled variance approach. The calculation results showed that the calculated t-value was 3.24. This value was then compared with the t-table value at 81 degrees of freedom, which was 1.99. Because the calculated t-value was greater than the t-table, the null hypothesis was rejected. Thus, the alternative hypothesis was accepted, which showed that the use of Flash media had a significant effect on student learning achievement compared to conventional learning in atomic structure material.

The results of this study indicate that the use of Flash media in chemistry learning has a positive impact on student achievement. This can be explained by the characteristics of Flash media, which can present abstract concepts more concretely through animated visualizations. In the topic of atomic structure, concepts such as the arrangement of subatomic particles and electron configuration are often difficult to understand when presented verbally only [39]. With dynamic visual displays, students can construct clearer mental representations of these concepts. This supports improved conceptual understanding, which ultimately impacts learning outcomes.

Furthermore, the use of Flash media also contributes to increased student engagement during the learning process. Interactive media allows students to not only passively receive information but also actively participate in the learning process [27]. This interactivity encourages students to explore the material independently, making the learning process more meaningful. This high level of engagement contributes to increased student motivation. With increased motivation, students tend to be more focused and strive for a deeper understanding of the material.

From a learning theory perspective, these results align with the constructivist approach, which emphasizes that knowledge is actively constructed by students. Flash media provides students with opportunities to construct their understanding through visual-based and interactive learning experiences [40]. This process helps students connect new concepts with prior knowledge. Thus, learning is not simply rote memorization but also fosters conceptual understanding. This is a crucial factor in improving student achievement.

On the other hand, conventional learning tends to be teacher-centered and provides little opportunity for students to actively interact with the material [41]. This method often leads to students having difficulty grasping abstract concepts. Without adequate supporting media, students rely solely on limited verbal explanations. This situation can hinder the process of internalizing concepts in the long term. Therefore, the use of innovative media such as Flash is an effective alternative to overcome this limitation.

The findings of this study also reinforce previous research that suggests that multimedia-based media can improve the quality of learning. However, the strength of this study lies in the application of Flash media, specifically designed for atomic structure. The integration of visualization and interactivity provides a more comprehensive learning experience [42]. This demonstrates that selecting media appropriate to the material's characteristics significantly influences learning success. In other words, media effectiveness is determined not only by the technology but also by its suitability for the material being taught.

Nevertheless, there are several things to consider when implementing Flash media. The success of using this media depends heavily on the teacher's readiness to manage technology-based learning [43]. Furthermore, the availability of supporting facilities, such as computers or projectors, is also a crucial factor. Without adequate resources, the media's effectiveness will not be optimal. Therefore, the implementation of learning media requires careful planning.

Overall, the use of Flash media can be an effective alternative learning innovation for improving student achievement in atomic structure. This media not only helps students understand abstract concepts but also increases motivation and engagement in learning. The implications of this research indicate that technology integration in chemistry learning is essential in the modern era. With the appropriate use of media, the learning process can be more engaging, interactive, and meaningful for students.

4. CONCLUSION

Based on the results of the research and discussion, it can be concluded that chemistry learning achievement using Flash Media is better than student learning achievement using conventional methods on the topic of students' Atomic Structure.

ACKNOWLEDGEMENTS

The author would like to thank the school for granting permission to conduct this research, as well as the teachers and students who participated in this study. Appreciation is also extended to all parties who provided support and assistance throughout the research process and the preparation of this article.

AUTHOR CONTRIBUTIONS

Conceptualization, I.M.K.B. and N.N.N.; Methodology, I.M.K.B.; Software, I.M.K.B.; Validation, I.M.K.B. and N.N.N.; Formal Analysis, I.M.K.B.; Investigation, I.M.K.B.; Resources, N.N.N.; Data Curation, I.M.K.B.; Writing – Original Draft Preparation, I.M.K.B.; Writing – Review & Editing, N.N.N.; Visualization, I.M.K.B.; Supervision, N.N.N.; Project Administration, I.M.K.B.; Funding Acquisition, N.N.N.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

Not applicable.

REFERENCES

[1] N. S. Rusli, N. H. Ibrahim, C. Hanri, and J. Surif, “E-Module problem-based learning on chemical equilibria to improve students’ higher-order thinking skills: An analysis,” *Int. J. Eval. Res. Educ.*, vol. 13, no. 1, pp. 454–465, 2024, doi: 10.11591/ijere.v13i1.25972.

[2] H. Tümay, “Systems thinking in chemistry and chemical education: A framework for meaningful conceptual learning and competence in chemistry,” *J. Chem. Educ.*, vol. 100, no. 10, pp. 3925–3933, Oct. 2023, doi: 10.1021/acs.jchemed.3c00474.

[3] J. Laohapornchaiphan and P. Chenprakhon, “A review of research on Learning activities addressing the submicroscopic level in chemistry,” *J. Chem. Educ.*, vol. 101, no. 11, pp. 4552–4565, Nov. 2024, doi: 10.1021/acs.jchemed.4c00156.

[4] M. Karonen, M. Murtonen, I. Södervik, M. Manninen, and M. Salomäki, “Heuristics hindering the development of understanding of molecular structures in university level chemistry education: The lewis structure as an example,” *Educ. Sci.*, vol. 11, no. 258, pp. 1–25, 2021, doi: 10.3390/educsci11060258.

[5] S. E. and A. E. W. Benjamin, “Studying the student’s perceptions of engagement and problem-solving skills for academic achievement in chemistry at the higher secondary level,” *Educ. Inf. Technol.*, vol. 29, no. 7, pp. 8347–8368, May 2024, doi: 10.1007/s10639-023-12165-x.

[6] F. Febriani, H. Hayyun, R. Nilawati, and A. Abdullah, “Analysis of comprehension difficulties in chemistry and their impact on student interest in learning,” *Jambura J. Educ. Chem.*, vol. 6, no. 2, pp. 103–112, 2024, doi: 10.37905/jjec.v6i2.25748.

[7] Y. Ding and Z. Qiao, “Carbon surface chemistry: New insight into the old story,” *Adv. Mater.*, vol. 34, no. 42, pp. 1–15, Oct. 2022, doi: 10.1002/adma.202206025.

[8] C. Xie *et al.*, “Defect chemistry in heterogeneous catalysis: Recognition, understanding, and utilization,” *ACS Catal.*, vol. 10, no. 19, pp. 11082–11098, Oct. 2020, doi: 10.1021/acscatal.0c03034.

[9] P. Doolittle, K. Wojdak, and A. Walters, “Defining active learning: A restricted systemic review,” *Teach. Learn. Inq.*, vol. 11, pp. 1–24, Sep. 2023, doi: 10.20343/teachlearninqu.11.25.

[10] J. G. M. Kooloos, E. M. Bergman, M. A. G. P. Scheffers, A. N. Schepens-Franke, and M. A. T. M. Vorstenbosch, “The effect of passive and active education methods applied in repetition activities on the retention of anatomical knowledge,” *Anat. Sci. Educ.*, vol. 13, no. 4, pp. 458–466, 2020, doi: 10.1002/ase.1924.

[11] P. Jadhav, H. Gaikwad, and K. S. Patil, “Teaching and learning with technology : Effectiveness of ICT integration in cchools,” *ASEAN J. Sci. Educ.*, vol. 1, no. 1, pp. 33–40, 2022, [Online]. Available: https://ejournal.bumipublikasinusantara.id/index.php/ajsed

[12] M. H. Romli, M. S. Cheema, M. Z. Mehat, N. F. Md Hashim, and H. Abdul Hamid, “Exploring the effectiveness of technology-based learning on the educational outcomes of undergraduate healthcare students: an overview of systematic reviews protocol,” *BMJ Open*, vol. 10, no. 11, p. e041153, Nov. 2020, doi: 10.1136/bmjopen-2020-041153.

[13] E. W. Prastyaningtyas, A. M. Almaududi Ausat, L. F. Muhamad, M. I. Wanof, and S. Suherlan, “The role of information technology in improving human resources career development,” *J. Teknol. Dan Sist. Inf. Bisnis*, vol. 5, no. 3, pp. 266–275, 2023, doi: 10.47233/jteksis.v5i3.870.

[14] O. Plakhotnik, V. Zlatnikov, I. Strazhnikova, N. Bidyuk, A. Shkodyn, and O. Kuchai, “Use of information technologies for quality training of future specialists,” *Rev. Amaz. Investig.*, vol. 12, no. 65, pp. 49–58, 2023, doi: 10.34069/ai/2023.65.05.5.

[15] M. F. Arifin, A. Rahman, M. E. Hendriyani, and I. Rifqiawatia, “Developing multimedia-based learning media on the digestive system using Adobe Flash Professional CS6 application for class XI,” *Res. Dev. Educ.*, vol. 2, no. 2, pp. 76–88, 2022, doi: 10.22219/raden.v2i2.19990.

[16] L. Tuhuteru, D. Misnawati, A. Aslan, Z. Taufiqoh, and I. Imelda, “The effectiveness of multimedia-based learning to accelerate learning after the pandemic at the basic education level,” *Tafkir Interdiscip. J. Islam. Educ.*, vol. 4, no. 1, pp. 128–141, 2023, doi: 10.31538/tijie.v4i1.311.

[17] R. S. Untari, W. Kamdi, A. Dardiri, S. Hadi, and D. Nurhadi, “The development and application of interactive multimedia in project-based learning to enhance students’ achievement for 2D animation making,” *Int. J. Emerg. Technol. Learn.*, vol. 15, no. 16, pp. 17–30, 2020, doi: 10.3991/ijet.v15i16.16521.

[18] I. Syamsudin, K. A. Ningsih, S. Rachmah, and R. Rasilah, “IT-based media in mathematics learning in elementary schools,” *J. Math. Instr. Soc. Res. Opin.*, vol. 3, no. 3, pp. 285–296, 2024, doi: 10.58421/misro.v3i3.273.

[19] C. Y. Lin and H. K. Wu, “Effects of different ways of using visualizations on high school students’ electrochemistry conceptual understanding and motivation towards chemistry learning,” *Chem. Educ. Res. Pract.*, vol. 22, no. 3, pp. 786–801, 2021, doi: 10.1039/d0rp00308e.

[20] I. I. Salame and J. Makki, “Examining the use of PhET simulations on students’ attitudes and learning in general chemistry II,” *Interdiscip. J. Environ. Sci. Educ.*, vol. 17, no. 4, pp. 1–9, 2021, doi: 10.21601/ijese/10966.

[21] M. Widyaningsih, S. Samsudi, and E. Ellianawati, “Flash interactive media to improve the mastery of light properties concept,” *J. Prim. Educ.*, vol. 9, no. 5, pp. 482–492, 2020, doi: 10.15294/jpe.v9i5.42991.

[22] C. Dewi, “The effect of flash-based interactive learning multimedia on the thematic learning outcomes of grade 5 students in elementary school,” *J. Pemikir. dan Pengemb. Sekol. Dasar*, vol. 10, no. 1, pp. 12–21, 2022, doi: 10.22219/jp2sd.v10i1.20026.

[23] N. Kerimbayev, Z. Umirzakova, R. Shadiev, and V. Jotsov, “A student-centered approach using modern technologies in distance learning: a systematic review of the literature,” *Smart Learn. Environ.*, vol. 10, no. 1, pp. 1–28, 2023, doi: 10.1186/s40561-023-00280-8.

[24] K. H. D. Tang, “Student-centered Approach in Teaching and Learning: What Does It Really Mean?,” *Acta Pedagog. Asiana*, vol. 2, no. 2, pp. 72–83, 2023, doi: 10.53623/apga.v2i2.218.

[25] W. Hadi *et al.*, “Enhancement of students’ learning outcomes through interactive multimedia,” *Int. J. Interact. Mob. Technol.*, vol. 16, no. 7, pp. 82–98, 2022, doi: 10.3991/ijim.v16i07.25825.

[26] S. E. Putri and F. Alyani, “Effect of using multimedia-based learning on motivation and learning outcomes,” *J. Penelit. Pendidik. IPA*, vol. 9, no. 11, pp. 9921–9927, 2023, doi: 10.29303/jppipa.v9i11.4396.

[27] K. Kustyarini, S. Utami, and E. Koesmijati, “the importance of interactive learning media in a new civilization era,” *Eur. J. Open Educ. E-learning Stud.*, vol. 5, no. 2, pp. 48–60, 2020, doi: 10.46827/ejoe.v5i2.3298.

[28] F. P. Rachmavita, “Interactive media-based video animation and student learning motivation in mathematics,” *J. Phys. Conf. Ser.*, vol. 1663, no. 1, pp. 1–6, 2020, doi: 10.1088/1742-6596/1663/1/012040.

[29] M. Chi *et al.*, “Implementation of the flipped classroom combined with problem-based learning in a medical nursing

course: A Quasi-experimental design," *Healthc.*, vol. 10, no. 12, pp. 1–11, 2022, doi: 10.3390/healthcare10122572.

[30] R. Khatoon and E. Jones, "Flipped small group classes and peer marking: incentives, student participation and performance in a quasi-experimental approach," *Assess. Eval. High. Educ.*, vol. 47, no. 6, pp. 910–927, 2022, doi: 10.1080/02602938.2021.1981823.

[31] J. E. Rudolph, Y. Zhong, P. Duggal, S. H. Mehta, and B. Lau, "Defining representativeness of study samples in medical and population health research," *BMJ Med.*, vol. 2, no. 1, pp. 1–7, 2023, doi: 10.1136/bmjmed-2022-000399.

[32] M. M. Rahman, M. I. Tabash, A. Salamzadeh, S. Abduli, and M. S. Rahaman, "Sampling techniques (probability) for quantitative social science researchers: A conceptual guidelines with examples," *SEEU Rev.*, vol. 17, no. 1, pp. 42–51, 2022, doi: 10.2478/seeur-2022-0023.

[33] Y. Touissi, G. Hjiej, A. Hajjioui, A. Ibrahimi, and M. Fourtassi, "Does developing multiple-choice Questioqs improve medical students' learning? A systematic review," *Med. Educ. Online*, vol. 27, no. 1, pp. 1–13, 2022, doi: 10.1080/10872981.2021.2005505.

[34] P. Rintayati, H. Lukitasari, and A. Syawaludin, "Development of two-tier multiple choice test to sssess Indonesian elementary students' higher-order thinking skills," *Int. J. Instr.*, vol. 14, no. 1, pp. 555–566, 2020, doi: 10.29333/IJI.2021.14133A.

[35] A. Sa'diyah and A. Lutfi, "Atomic structure teaching Module with PhET simulation to increase student motivation and learning outcomes," *Hydrog. J. Kependidikan Kim.*, vol. 11, no. 4, pp. 459–468, 2023, doi: 10.33394/hjkk.v11i4.8436.

[36] W. Ramadanti and R. A. Fikroh, "Make a match assisted scramble learning model for learning motivation and student learning outcomes in atomic structure material," *J. Penelit. Pendidik. IPA*, vol. 10, no. 8, pp. 5749–5758, 2024, doi: 10.29303/jppipa.v10i8.6768.

[37] A. Yonar, H. Yonar, M. Demirsoz, and M. A. Tekindal, "A comparative analysis for homogeneity of variance tests," *J. Sci. Arts*, vol. 24, no. 2, pp. 305–328, 2023, doi: 10.46939/j.sci.arts-24.2-a06.

[38] A. N. Fazlin and M. Nora, "An overview of homogeneity of variance tests on various conditions based on Type 1 error rate and power of a test," *J. Qual. Meas. Anal.*, vol. 18, no. 3, pp. 111–130, 2022, [Online]. Available: http://www.ukm.my/jqma

[39] N. Zarkadis, G. Papageorgiou, and A. Markos, "Understanding quantum numbers: students' verbal descriptions and pictorial representations of the atomic structure," *Int. J. Sci. Educ.*, vol. 43, no. 13, pp. 2250–2269, Sep. 2021, doi: 10.1080/09500693.2021.1959080.

[40] E. Y. Harahap and Y. E. Saragih, "Improving student learning outcomes through the utilization of flash card learning media in slamic religious subjects at SD Negeri 0201 Binanga," *ETNOPEDAGOGI J. Pendidik. dan Kebud.*, vol. 1, no. 1, pp. 170–181, 2024, doi: 10.62945/etnopedagogi.v1i1.590.

[41] M. A. Alam, "From teacher-centered To student-centered learning: The role of constructivism and connectivism in pedagogical transformation," *CONFLUX J. Educ.*, vol. 11, no. 2, pp. 154–167, 2023, [Online]. Available: https://cjoe.naspublishers.com

[42] A. Alam and A. Mohanty, "Educational technology: Exploring the convergence of technology and pedagogy through mobility, interactivity, AI, and learning tools," *Cogent Eng.*, vol. 10, no. 2, pp. 1–37, 2023, doi: 10.1080/23311916.2023.2283282.

[43] T. Arochman and P. B. Fortinasari, "Implementation of technology-based learning by pre-service teachers during teaching practice program," *Premise J. English Educ.*, vol. 13, no. 1, pp. 126–145, 2024, doi: 10.24127/pj.v13i1.8988.