Jurnal Pendidikan Kimia (JPKIM)
p-ISSN: 2085-3653| e-ISSN: 2549-3116
https://jurnal.unimed.ac.id/2012/index.php/jpk/index

OPEN ACCESS
10.24114/jpkim.v16i3.61477
J. Pendidik. Kim 2024, 16(3), 230– 237

Original Research Article

The development of a project-based multimedia and its effectiveness in improving students' higher order thinking skills about chemistry bonding concept

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Citation: Kholid, I., Harizon, H., & Hasibuan, M.H.E. (2024). The development of a project-based multimedia and its effectiveness in improving students' higher order thinking skills about chemistry bonding concept. Jurnal Pendidikan Kimia (JPKIM), 16(3), 230 – 237. https://doi.org/10.24114/jpkim.v16i3.61477

ARTICLE INFO

Keywords:
Chemistry bonding concept;
Higher order thinking skills;
Multimedia learning;
Project based learning

History:
♦Received - 15 Jul 2024
♦Revised - 19 Dec 2024
♦Accepted - 19 Dec 2024

ABSTRACT

This study aimed to develop a learning multimedia which is based on project-based learning (PjBL) and to investigate its effectiveness in improving students' higher order thinking skills (HOTS) in the concept of chemistry bonding. This study used a research and development (R&D) design involving the method of Lee and Owen which consisted of five stages namely analysis, design, development, implementation, and evaluation (ADDIE) to develop the intended multimedia. The effect of the developed multimedia use on students' HOTS was investigated using a one group pretest-posttest experimental design with a class of secondary high school students in Jambi city Indonesia. The research of analysis towards the development process showed that the project-based multimedia learning was successfully developed using the ADDIE method. This involved some validation results from some experts that include the chemistry expert and media learning expert who declared that it was valid and feasible to use. The results of experiments showed that the implemented multimedia was effective in increasing the participant students' HOTS after the learning process. The effectiveness was affirmed by the paired t-test (p-value = 0.000<0.05) indicating that there was a significant difference between the students' HOTS pretest and posttest. This effectiveness was confirmed by the N-gain value of 0.58 which means that the students had experienced 58% HOTS improvement. This can thus be concluded that the developed project-based multimedia was valid and effective in improving students' HOTS in the concept of chemistry bonding.

Introduction

Education plays a vital role in cultivating and improving human resource of a country. Through education, the development of students' potency, personality, intelligence, skills as well as morals can be directed in a good manner. To achieve those goals, Indonesia government until now has been revising its education law and national curriculum. The education law of Indonesia namely the SISDIKNAS Law No.20 of 2003 truthfully stated that education is an intended and well-planned program to provide a suitable learning atmosphere and learning process in order for students to actively develop their potency in various aspects including religion, self-control, personality, intelligence, morals, as well as social skills. This is relevant with Mayes (2015) who stated that the goals of education more relate to a very comprehensive formulation about what it should be achieved and various expected capabilities students should possess, in a harmony with values and philosophy they adhere to.

In the essence of science learning, one capability amongst those that students are prescribed to possess is an ability to perform higher order thinking skills (HOTS). HOTS refers to higher level cognitive abilities that include ability in making analyses, evaluation, and creation (Octavia, 2020). In implementation, teachers need to design a learning activity that encourage student to analyze data, to evaluate information, and to create new information. According to Widiawati et al. (2018), HOTS – consisted of ability in making analyses, evaluation, and creation- is the required skills owned by students in the 21st century for preparing themselves to solve various problems in life. Such learning activity use is strongly recommended by current implemented curriculum of Indonesia namely the Kurikulum Merdeka or Independent Curriculum aimed at encouraging students to rehearse their ability to think critically and creatively (Kollo & Suciptaningsih, 2024).

However, based on our daily observation as researchers and educators, it is seen that some secondary high school (SHS) students in Jambi city Indonesia still have problems with HOTS. When they were given cognitive level 4 (C4) or analysis-related problem in chemistry that is categorized as the HOTS problem, they obtained low score for it. They were apparently seen still lack of enough organizing ability. They faced problem in identifying chemistry elements in a way to be together become a mutual related chemical structure. That anecdotal data was parallel with the results of a survey we conducted in some SHS in Jambi city Indonesia in 2023; only few students who have HOTS and more than 60% of students are lack of capability to analyze. In fact, according to Misrom (2020), capability to think in higher level is urgent as this one amongst aspects to increase the quality of human resource, particularly in the 21st century, where everyone should be able to analyze every problem and to make decision, not only in science including chemistry, but also in life. The facts about the low HOTS of students in Jambi were similar with the results of previous authors (Yen & Halili, 2015; Niswara et al., 2019; Hasyim, 2020; Yuliana et al., 2021) who also found that students have low HOTS. The facts about the low HOTS of students in Jambi – even though the data are not representative for the global population of students in Indonesia- seems contributive to the low achievement of Indonesian students in PISA since 2006 (Yusmar & Fadilah, 2023).

Chemistry is one branch of science. Chemistry is an abstract knowledge gained and developed based on doing experiments to answer questions about what, why, and how the natural phenomena take place, especially related to the composition, structure and properties, transformation of dynamics, and energetics of substance (House & House, 2015). To possess a comprehensive chemistry understanding, students need ability to think in higher level involving ability to think critically and creatively. Lack of those abilities – with regard of the complexity of chemistry itself- may have caused many students fail in chemistry. Unsurprisingly, that may have caused most students consider chemistry difficult.

Regarding the above proposition, a result of our preliminary research in a SHS in Jambi city Indonesia in 2023 provided a supporting data. We found that 19 out of 30 students have felt chemistry a difficult subject and one of the concepts is the chemistry bonding. Moreover, we also found that 17 out of 30 students failed in solving problems related to chemistry bonding. These results were similar with the results of previous authors (Yen & Halili, 2015; Niswara et al., 2019; Hasyim, 2020; Yuliana et al., 2021) who also found that students have low HOTS. Suggestions thus were submitted by teachers to foster the students' HOTS which spanned from the utilization of a particular learning model such as project-based learning (PjBL) in chemistry lessons to the procurement of a purposefully-designed learning material such as a multimedia learning.

Project-based learning is a learning activity which involve students in projects that require students to collaborate, to make use of critical thinking, to solve problems, and to produce products (Anafiza & Djukri, 2017). The Independent Curriculum is recommending chemistry learning to be enacted in the soul of project-driven tasks. Those goals can be done by teachers by utilizing daily life issues to become the students' projects assisted by related learning materials (Anafiza & Djukri, 2017). So, PjBL can be one approach supporting the development of HOTS as it invites student to actively participate in learning and apply knowledge in real situation, and to think critically to solve complex problems. All these visions are in line with the visions of independent curriculum for the development of education quality in Indonesia.

Considering the above description, a successful learning will generate expected learning outcomes when it is not only enacted under a compatible learning model but also is facilitated by a suitable learning material. This means that a suitable learning media is thus critically needed to accelerate the enhancement of learning outcomes. According to Benesova (2017) an appropriate use of teaching materials in response to the needs of the 4.0 era and is mostly liked by generation Z is the media which contains audio, visuals, and problems/questions along with the discussions. This type of media is widely called a multimedia. Habib (2021) described that a multimedia is a combination of various media such as text, images, audio, video, animation, and interactions used to convey information or messages to users in a more interesting and effective way. In the technology context, a multimedia usually refers to the computer application or system that allows user to access, to manipulate, and to obtain information in diverse forms like images, sound, video, text, and animation. Multimedia can be found on various platforms such as websites, mobile applications, video games and social media. Moreover, Yahya and Lutfi (2023) states that a multimedia can give a richer and more interesting experience for user rather than a single medium. By providing information in various forms, a multimedia can help users understand and remember information better, as well as to increase interaction and engagement between users and the content.

Given the benefits of the use of multimedia on learning outcomes, previous studies are reviewed. Hasyim (2020) found that the use of a multimedia which was based on ICT and Blended PjBL showed significant effectiveness in developing students HOTS. This was also similar with the results of Yen & Halili (2015) that the HOTS can be increased using an effective multimedia. Niswara et al. (2019) also observed that the use of a media puzzle based on PjBL was effective in enhancing students' HOTS. In addition, Yuliana et al. (2021) also found that the use of an interactive media based on PbL was effective in increasing students' HOTS in physics subject.

In advance to the above findings, Handayani (2021) further states that a good learning material is just not adequate to create a meaningful learning, but it needs to be concurrent with learning process which is projected to generate expected learning outcomes. Therefore, in this study, a learning process that is able to facilitate students to obtain HOTS is PjBL and a learning media that is supportive for the promotion of the students' HOTS is multimedia which is based on project. All be it, this study aimed at helping students increase their HOTS by developing a multimedia which is based on PjBL in the concept of chemistry bonding followed by an investigation towards its effectiveness in promoting the students' HOTS. Therefore, this study on purpose: (1) to develop the project-based multimedia which is believed potential to increase students' HOTS in the concept of chemistry bonding; (2) to measure the validity of the multimedia; and (3) to investigate the effectiveness of the multimedia in promoting the students' HOTS in the concept of chemistry bonding.

Materials and Methods

Research design

This study used a research and development (R&D) design involving the method of Lee & Owen (2009) which consists of five stages namely analysis, design, development, implementation, and evaluation (ADDIE) to develop the intended multimedia. The multimedia was developed using several software that includes Power Point apk and some websites such as quizizz and edpuzzle as the platform to design. This study was conducted in the early 2024 with a chemistry female teacher aged between 30-40 and a class of her secondary high school (SHS) students in Jambi city Indonesia. Their involvements were confirmed by consent forms. The conduct of the stages is described below:

The analysis stage: this stage aimed at investigating the needs analysis prior to the development process. This was mainly to collect data about the students' HOTS, the prevalent use of PjBL, the chemistry concept to be involved, and the pre-existing learning media the school possessed.

The design stage: this stage aimed at designing the multimedia. This was mainly to determine the chemistry content, the multimedia specification, the structure, and the storyboard. The goal of this stage was to obtain a prototype multimedia which was further developed in the development stage.

The development stage: this stage aimed at transforming the prototype into a more developed multimedia. This included the steps of expanding the prototype into a more appropriate multimedia involving cycles of consultations and revisions between the first author/researcher and a chemistry expert and a media expert, which all the feedbacks were recorded in questionnaires. As a result, a validation statement was acquired based on those experts' judgements which indicated that the multimedia was conceptually and procedurally valid and was thus permitted to be implemented with a small group of the participant students and the teacher to obtain a practical validity. The latter validity was obtained from the participants' feedback after they used the multimedia; and all the feedback were recorded in questionnaires. In case they agreed that the multimedia was already valid and feasible to use, thus the product was worthily brought into the next stage. Otherwise, the multimedia was reconsulted to the experts for revisions.

The implementation stage: this stage was conducted to have a real-classroom validity by implementing the multimedia with a class of the participant students and the teacher. Prior to the implementation a pretest was administered, and after the implementation they were encouraged to give feedback towards the validity of the multimedia using a questionnaire. A posttest was also administered after the implementation aimed at investigating the effectiveness of the multimedia in promoting the students' HOTS. The effectiveness was investigated using a one group pretest-posttest experimental design and the analyses was conducted using a dependent t-test in terms of the data was normal and homogeny. Otherwise, a Wilcoxon test is the alternative for it.

The evaluation stage: this stage aimed at investigating how valid the multimedia was and how effective the multimedia in promoting the students' HOTS was. The validity conclusion was taken from the above described conceptual, procedural, and practical validities. Meanwhile, the effectiveness conclusion was taken from the effectiveness test described above. In case that the multimedia had been valid thus the development process was allowed to be terminated and the multimedia was stated successfully developed. Furthermore, in case that the use of the multimedia had been effective in promoting the students' HOTS thus the development process was also allowed to be terminated and the multimedia was stated successfully developed. In case some discrepancies appeared, other revisions may be retaken to refine the multimedia. Therefore, this stage was also called the summative revision.

Research instruments

This study used several instruments to collect data. These included interviews, questionnaires, and HOTS tests. The interviews were used in the analyses stage to collect data about the level of students' HOTS, the chemistry teaching approach prevalently enacted by the teacher, the difficult concepts of chemistry mostly sounded by the students, and the learning media pre-existing possessed by the school. The instruments were constructed based on the need of the study and were collected from the teacher and the students.

In addition, the questionnaires were used to collect data in the form of feedback from the chemistry expert, the media expert, the teacher, and the students during the development and the implementation stage. These were respectively related to the correct use of the chemistry bonding concepts and formula/symbols, the validity of the multimedia, and the usefulness/feasibility of the multimedia. The questionnaires were constructed – in sequence- based on the concept of chemistry (House & House, 2015), the 12 principles of multimedia learning of Mayer (2017), and the lesson dymanics experienced by the teacher and the students when using the multimedia. Meanwhile the HOTS tests were constructed based on the chemistry syllabus of secondary school in Indonesia.

Chemistry learning and data collection

The developed multimedia about the chemistry bonding content was implemented in three meetings in the classroom with the pre-mentioned participant students and their chemistry teacher. At the start of the lesson, the students were encouraged to take a pretest aimed at identifying their initial HOTS. After the pretest, the teacher conducted the lessons facilitated by the multimedia to deliver the chemistry bonding concepts and to nurture the students' HOTS by asking them to learn some examples of HOTS problems followed by guiding them to solve similar HOTS problems contained in the multimedia. At the end of the lesson, the students were invited to give opinions about the usefulness/feasibility of the multimedia using a questionnaire. Finally, a posttest was also administered aimed at collecting data about the students' HOTS after the lesson.

Regarding the data collection, the data from the posttest and the pretest were useful for investigating the effectiveness of the multimedia in promoting the students' HOTS. Since this study only used one class of students, thus the effectiveness was measured using a one group only pretest-posttest experimental design. The diagram of the experiment is as follows.

O1 → X → O2

Notes:
O1 is pretest and O2 is posttest
X is the treatment, the implementation of the multimedia

Data analyses

The data collected were analyzed using various techniques. The data from interviews in the initial stage were analyzed using the descriptive qualitative method. This was useful to establish the need of developing such multimedia which was expected potential in helping the participant students promote their HOTS. The data from the questionnaires were analyzed using the descriptive statistics method. This was useful to measure the validity and feasibility of the multimedia. Meanwhile, the data from the pretest and the posttest were analyzed using N-gain test as well as a dependent t-test in terms of the data was normal and homogeny. Otherwise, a Wilcoxon test is the alternative for it. The N-gain score is a difference between students' initial scores and final scores which indicates the gain of HOTS from the pretest to the posttest (Hake, 2002). The formula is as follows.

Results

The development process of the project-based multimedia

The multimedia development was carried out using the Lee & Owens (2009) approach including the ADDIE stages. At the analysis stage, the researcher conducted a need analysis including data about curriculum, the difficult chemistry concept to be involved, the prevalent use of PjBL, the students' HOTS, and the pre-existing learning media the school possessed. The important and compacted data are compiled in Table 1.

Table 1. The results of analysis stage

No	Questions	Answers
1	What curriculum you are using in this school?	Independent Curriculum
2	How do your students see chemistry, particularly the chemistry bonding concept?	Students consider that the chemistry particularly the chemistry bonding concept is difficult to master
3	Have you ever used the Project-based learning (PjBL) model in the learning process?	Seldom as it takes time
4	What is the level of students' Higher Order Thinking Skills (HOTS) in the concept of chemistry bonding?	Some students already have HOTS and some others are still struggling for it
5	Have you ever implemented, given questions, or trained HOTS to students?	I have tried applying HOTS questions, but students still have difficulty on it
6	How is the availability of learning media, facilities, and infrastructure in this school?	It is adequate. We have wifi, projectors and school computers. We have some learning media but we have not had a multimedia about PjBL and HOTS. I suggest the development of it.

At the design stage, some aspects were determineed; the chemistry content, the multimedia specification, the structure, and the storyboard. The goal of this stage was to obtain a prototype multimedia. The important and concentrated data are as follows:

- The chemistry bonding was chosen to be the concept used in the multimedia
- The specification of the multimedia was based on PjBL and HOTS, was consisted of video, audia, pictures, and texts. It has an apk format and can be operated using a smartphone with the Android 4.4 operating system.
- The structure of the multimedia contains cover and introduction, manual instructions, learning outcomes, learning flow, learning objectives for chemistry bonding concept, project guide, quiz, and link to upload tasks.
- The storyboard or the blue print of the multimedia which was based on the above structure was designed in a flow of figures and functions.

At the development stage, advices were received from the experts towards the prototype; and the simplified important data are as follow.

- After two cycles of revisions on errors that were mainly about the mistyped of chemistry formula and symbols with the mean scores of 51 (63.75%) and 75 (93%) respectively, the chemistry expert finally stated that the multimedia had been valid and eligible to be tried out.
- Similarly, after two cycles of revisions on errors that were mostly about the cover, the color, the video, and the syntax of PjBL with the mean scores of 60 (63.16%) and 73 (97%) respectively, the media expert finally stated that the multimedia had been valid and eligible to be tried out. These validities were called the conceptual and the procedural validity. This means that the multimedia development process had been correct and obeyed the PjBL concept and syntaxes as well as the rules of research and development (R&D) method.
- In addition, the validation was also carried out by the teacher and by few students. This is called the practice validity. After using the multimedia in two lessons with her students, the teacher meanly scored the multimedia of 67 (89%) and 69 (92%). Similarly, some 12 students meanly scored the multimedia of 67.1 (89.4%). These data means that the multimedia has been valid and worthy for a real classroom use.

At the implementation stage, the validation was carried out from a real-class of 30 students. After using the multimedia, the students meanly scored it 71.4 (95%). This means that the multimedia had been valid and worthy for future use in chemistry lessons. At this stage, a pretest and a posttest were also administered with the students to investigate the effectiveness of the multimedia in promoting the students' HOTS. Based on the t-test, it was found that the developed multimedia had been effective in promoting the students' HOTS; however, the details of the effectiveness will be presented in the next sub-section.

Finally, at the evaluation stage, conclusions were taken. Based on the data presented in the previous stages, the researchers concluded that the development process had been successful. The multimedia had been valid, worthwhile to be used in a real chemistry classroom, and effective in promoting the students' HOTS. Therefore, the development process was allowed to be terminated and the multimedia was stated successfully developed under the ADDIE approach.

The effectiveness of the multimedia

The effectiveness measurement used the pretest and posttest scores. Table 2 indicates both scores in which the posttest (16.3) was higher than the pretest (11.03). The scores difference is reasonable as at the beginning of the study, the students had not possessed enough knowledge about the chemistry bonding concepts and the HOTS problems (pretest score). Later, as the effect of the use of the multimedia in the chemistry lessons, they gained more knowledge about those (posttest score). The data is supported by the N-gain score of 0.58 (58%) which indicates that the students had experienced 58% of promoted knowledge.

Table 2. The average scores of the pretest and the posttest of the students' HOTS

Class	Average Pretest	Average Posttest	N-gain Index	Criteria
Participants	11.03	16.3	0.58	Medium

The preliminary finding about the knowledge gain is not adequate to justify the effectiveness. Therefore, a dependent (paired) t-test had been applied for it. Prior to the t-test, the data was measured and found normal (p-value = 0.427 > 0.05) and homogeny (p-value = 0.328 > 0.05). Data in Table 3 and 4 present the normality and homogeny values.

Tabel 3. The normality of the data

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PretestHigherOrderThinkingSkill	.195	30	.005	.927	30	.427
PostestHigherOrderThinkingSkill	.178	30	.047	.912	30	.087

a. Lilliefors Significance Correction

Tabel 4. The homogeny of the data

Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Hasil Nilai Higher Order Thinking Skill	Based on Mean	.947	1	58	.328
	Based on Median	1.006	1	58	.311
	Based on Median and with adjusted df	1.006	1	48.854	.311
	Based on trimmed mean	1.001	1	58	.313

Therefore, since the data was normal and homogeny, thus the use of the dependent (paired) t-test was allowed. Based on the t-test, it was found that there was a significant effect of the use of the multimedia on the students' HOTS. Data in Table 5 indicate that there was a significant difference between the pretest score and the posttest score (sig 2-tailed p-value = 0.00 < 0.05).

Table 5. The results of dependent t-test

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Pretest - Posttest	-20.667	7.626	1.392	-23.514	-17.819	-14.843	29	.000

Discussion

The development process and the validity of the project-based multimedia

Based on the results presented above, it is apparent that the development of the project-based multimedia in the concept of chemistry bonding had been successfully carried out. This finding was reasonable as the process had followed and complied with all the procedures and techniques prescribed by Lee & Owen (2009). Some points of thinking are discussed below.

The process was started by identifying the need analysis and the data was presented in Table 1. The data in Table 1 informed the developer/researcher that the students still considered chemistry a difficult subject. They were rarely involved in PjBL. They possessed low HOTS and their school did not have a multimedia which is based on project and HOTS. The such preliminary data may have been contributive strongly to the development process as they directly revealed what the students really needed to promote their HOTS. As a result, those data may have inspired the customization of the multimedia to fulfill the students' need. In short, the development process had been prescribed by the need analysis data.

In addition, at the design stage, the construction process also complies with the rules of Lee & Owen (2009) which instruct the design process to utilize the need analysis data, not other than that. For example, the involvement of the chemistry bonding in the multimedia was informed by the students' voices, not by the researcher's preference. The structure of the multimedia was not only contained chemistry bonding concept but also project, quiz, and tasks which challenged the students to deal with. The specification of the multimedia was informed by the students' need which was the project-based and HOTS. This stimulated the meaningful learning principle and is explainable using the cognitive theory of Ausubel (Anwar et al., 2023). Subjects are easier to understand when the material-to-learn is felt to be meaningful and cope with the interest of the students. This means that by designing the multimedia based on PjBL had invited the students to make use of reflective thinking process so that learning becomes meaningful for them.

Moreover, the multimedia was also designed to utilizing video, audio, pictures, and texts as well as compatible with smartphone and the android 4.4 operating system which was the world of gen Z, the participant students. According to Chang (2022) that android-based multimedia can increase the students' learning outcomes as it has advanced and systematic features, can be accessed easily, more practical and efficient, equipped with material-related pictures, videos, feedbacks, educational games and evaluation. In a similar tone, Yuliati (2018) criticized that development of multimedia learning which merely contain concepts, exercises, questions and quizzes but fails to involve technology which is very important for student to fulfil the demands of the 21st century learning cause boredom on students. The such use of the need analysis data in the design stage may have made the customization of the multimedia became better.

Finally, the successful development of the multimedia which involved pictures, audio, videos, and text may have been grounded by some theories such as the cognitive theory of Piaget (Barraouillet, 2015) and the multimedia learning of Mayer (2017). From these theories, the design of multimedia which inserted pictures, audio, videos, and text may have stimulated the audio and visual sensors of the students that is commonly called the two channels for processing information. This was why the development of the multimedia successful.

After having been designed, the prototype of the multimedia was further developed and validated by the experts. This is called the conceptual and procedural validity. The validity of the multimedia was achieved by the conduct of cycles of advices and revisions between the researcher and the experts; and once again this activity complied with the rule of Lee & Owen (2009) which instructs the urgency of having validation from experts. The scores between the cycles of revisions can be seen in the results section above. The validation statement of the experts means that the multimedia development process had been correct and obeyed the PjBL concept and syntaxes as well as the rules of research and development (R&D) method. The such validity obtained from the experts may have come from their high respected expertise which produced good quality advices.

In addition, the validation was also asked from the teacher and a small group of students. This is called the practice validity. This also complied with the rule of Lee & Owen (2009) which instructs the urgency of having feedbacks from users; the teacher and the students. The scores of the teacher and the students can be seen in the results section above. The validation statement from the users means that the multimedia has been valid and worthy for a real classroom use. The such validity may have come from the users' readiness and courage to provide positive feedbacks. Finally, the validity of the multimedia may have also been obtained by the openness and ready-to-learn of the researcher to accept advices and to revise the multimedia. Otherwise, the multimedia would probably never be valid. At the implementation stage, the validation was carried out from a real-class of 30 students. This also complied with the rule of Lee & Owen (2009) which instructs the urgency of having feedbacks from a full class of students. The scores of the students can be seen in the results section above. The validation statement from a class of students means that the multimedia had been valid and worthy for future use in chemistry lessons. This was not surprising as the validation from a bigger group of students was usually concurrent with the validation from a small group of students as they were from a same school which have a same educational condition. Finally, at the evaluation stage, conclusions were taken that the development process had been successful. The multimedia had been valid and worthwhile to be used in a real chemistry classroom. Once again, this was reasonable since all the procedures and techniques prescribed by Lee & Owen (2009) under the ADDIE approach was strictly followed during the development process. Nieveen (1999) confirmed that when a learning material is developed in a conformation with the grand design and blue print, fulfils the end users' needs, and is feasible to be used, thus a validity status is not impossible to be achieved.

The effectiveness of the multimedia

Based on the results presented above, it is apparent that the project-based multimedia in the concept of chemistry bonding had been effective in promoting the students' HOTS. The data in Table 2 affirmed that the students experienced promoted HOTS from the pretest to the posttest. They obtained HOTS promotion around 58% of N-gain index. According to Olivia & Muchlis (2021) that the 58% gain had been adequate to be inferred as an effectiveness. They stated that an electronic multimedia can be categorized effective if it is able to help students gain promoted knowledge minimum of 0.3 or 30%.

The gain-based effectiveness is not convincing to be used in making a more solid effectiveness of the use of the multimedia in promoting the students' HOTS. Therefore, an inferential statistical technique was used for it. A dependent or paired sample t-test had been chosen as this study involved only one class of students in two different tests; the pretest and the posttest. This is supported by Ross & Wilson (2017) who affirmed that the use of the paired sample t-test is correct when a study aimed at looking at a difference of mean scores of a group of students in two different points/time.

Based on the data in Table 5 it is seen that the use of the multimedia was effective in promoting the students' HOTS. It was found that there was a significant difference between the pretest score and the posttest score (sig 2-tailed p-value = 0.00 < 0.05). This effectiveness was similar with the results of previous authors. Hasyim (2020) found that the use of a multimedia which was based on ICT and Blended PjBL showed significant effectiveness in developing students HOTS. This was also similar with the results of Yen & Halili (2015) that the HOTS can be increased using an effective multimedia. Niswara et al. (2019) also observed that the use of a media puzzle based on PjBL was effective in enhancing students' HOTS. In addition, Yuliana et al. (2021) also found that the use of an interactive media based on PbL was effective in increasing students' HOTS in physics subject.

The effectiveness characteristics of the multimedia developed in this study was rational. As pre-mentioned above, it is already conceptually, procedurally, and practically valid prior to its use in the implementation stage with the big group of students. The such validity must be the important pinpoint which contributed to the effectiveness showed in the implementation stage with the students. The customized developed multimedia which was inspired by the students' voice and needs may have been the critical factor that made the multi effective in helping the students improve their HOTS.

Conclusion

Based on the findings, some conclusions are taken. The development process of the project-based multimedia to increase students' HOTS in the concept of chemistry bonding was carried out successfully under the ADDIE approach of Lee and Owens' development model. Those involve the collection of need analysis, making the specifications and blue print of the prototype, several cycles of advices and revisions, classroom trial, and summative evaluation. Those strict procedures made the multimedia valid which was declared by the chemistry expert, the teacher, and the students. This means that the multimedia was eligible for future use in a real chemistry lesson. Finally, it was concluded that the multimedia was effective in promoting the students' HOTS in the concept of chemistry bonding.

Conflict of Interests

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

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