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Google Classroom Interactive in Project-based Learning Model Accompanied by Formative Assessments to Improve Understanding of Dynamic Fluid Concepts

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Abstract
This study aims to create interactive learning media using Google Classroom combined with the Project-based Learning (PjBL) model and formative assessment to improve the understanding of 11th-grade students about fluid dynamics. The method used is Research and Development (R&D) with ADDIE steps, which consist of analysis, design, development, implementation, and evaluation. The results of the evaluation by experts showed that the media was highly valid, with a validity score of 90% from subject matter experts and 91.67% from media experts. A limited trial at SMA Negeri 2 Pare involved two classes: one experimental class that used the media, and one control class that did not use the media. Analysis results showed a significant difference between the learning outcomes of the two groups. The N-Gain calculation indicated a high increase in understanding in the experimental class (74%) and a low increase in the control class (30%). Google Classroom-based interactive media with PjBL and formative assessment has proven valid, practical, and effective in improving understanding of fluid dynamics concepts. Active student involvement in projects, Google Classroom access that can be done anywhere and anytime, and continuous teacher feedback to students are factors in improving understanding of fluid dynamics concepts. The use of this learning strategy is an alternative to support learning in the National Curriculum at the secondary school level.

Keywords:
Conceptual Understanding; Fluid Dynamic; Google Classroom; Project-Based Learning; Formative Assessment

INTRODUCTION

Dynamic fluids are one of the physical concepts whose application is seen in daily life. The concept of dynamic fluids is studied by students at the high school level (Putri et al., 2023), where students learn the characteristics of ideal fluids, flow discharge, continuity equations, Bernoulli's laws, and Torricelli theory (Permana et al., 2021). However, this topic is often seen as difficult by most students (Suherly et al., 2023). Various factors contribute to the low understanding of students. Learning in the classroom is still traditional, teacher-centered, and the time allocation is inadequate (Cahya et al., 2024). Then Rahmadani et al. (2023), stating that teachers also often rely on one textbook as the main source, Mubarok & Anugrah (2024), also stated that applying inappropriate methods is still dominating, while the learning media used is not interactive enough (Sadikin & Hamidah, 2020), and the active involvement of students is low (Maulana & Pathoni, 2018). As a result, students tend to passively just sit and listen and are reluctant to express opinions (Suherly et al., 2023), which causes them to have difficulty understanding phenomena related to dynamic fluids (Nissa et al., 2021). If the basic concepts have not been well developed, the development of physics knowledge will be hampered due to its abstract nature (Rafiqah et al., 2019). One of the solutions to improve students' understanding of the concept of dynamic fluids is through the use of digital media that is more interactive and supports active project-based learning.

Increasing understanding of concepts is created by supporting students' way of thinking while solving a problem. Concept comprehension refers to an individual's ability to understand a concept, including simplifying information to make it easier for others to understand, providing interpretation, and applying it in a relevant context (Lumbantobing et al., 2021). Apriliyani (2023), stated that understanding concepts is a crucial element in the learning process. When students understand concepts well, they will be better able to master various subjects because they can relate one material to another. This means that the ability to solve problems does not solely depend on memorizing formulas. According to Lumbantobing et al. (2021), students who do not understand concepts will have difficulty in achieving high-level thinking skills. According to Trianggono (2017), a deep understanding of concepts includes students' ability to define, identify, and relate various concepts from various perspectives. This ability allows students to build connections between physical concepts and develop more meaningful ways of thinking (Wardani, 2020). The negative impact of low understanding of the concept of dynamic fluids is the misconception between the concept and its application in daily life, resulting in a low level of learning completeness (Iswana et al., 2016). Thus, the understanding of physical concepts becomes the basis for solving problems, both theoretical and related to real life. To support the achievement of this understanding, one of the approaches that can be used is the application of assessment or assessment techniques.

The development of digital technology in education is very important in the era of the Industrial Revolution 4. 0. One of the breakthroughs from Google aimed at supporting education is Google for Education (Bagas et al., 2017). Among the various services available, Google classroom is considered the most suitable for modern learning characteristics, because it supports the active participation of teachers and students, so it is considered suitable for application in education in Indonesia (Bagas et al., 2017). Setyaningsih & Hidayat (2021), noted that Google classroom assists teachers in designing, distributing, and organizing assignments efficiently, providing direct feedback, and enabling communication that is not hindered by space and time constraints. The platform also offers features such as discussion forums, assignments, quizzes, subject matter, academic calendars, and attendance logging, which not only simplify classroom management, but also support student learning independence (Ibrahim et al., 2023; Buhungo, 2021). Indarwati (2021), emphasized that Google classroom is very effective for distance learning. Meanwhile, Yanti et al. (2021), showed that the combination of PjBL, mobile learning, and Google classroom can increase motivation and learning outcomes. Findings from Buhungo (2021), also confirm that Google classroom is the right means to implement web-based PjBL and has been proven to be able to improve student learning achievement. As such, the platform is flexible and has great potential to integrate with project-based learning models.

The application of the project-based learning model (PjBL) can be an alternative solution in overcoming the lack of direct interaction that often occurs when using Google Classroom. Through PjBL, students are encouraged to collaborate and communicate actively throughout the learning process. This approach utilizes projects as well as a variety of activities as a means of learning, allowing students to engage directly and develop problem-solving skills. In addition, students are also given the opportunity to work in groups and create products that have real benefits (Melinda & Zainil, 2020). In practice, PjBL emphasizes the active involvement of students in collecting and utilizing information for meaningful purposes, both personally and socially. Although the learning activities are applicable, they are still aligned with the achievement of basic competencies according to the curriculum. With these advantages, this model contributes to creating more active and directed learning, although there are still some limitations that need to be considered in its implementation.

The application of formative assessments that provide feedback in a continuous and constructive manner can overcome various weaknesses in the PjBL model. Through this approach, students are encouraged to actively revise their mistakes and improve understanding during the learning process. Formative assessment is an evaluation method that aims to provide information to teachers and students about steps that can be taken to improve the learning process (Quote: Jafar et al., 2024). During learning activities, these assessments are used to monitor the achievement of learning objectives. Formative assessments have an important role because they allow teachers to monitor students' learning progress on a daily basis (Simanjuntak et al., 2019). According to the findings of Sari et al. (2019), the application of formative assessments in project-based learning can significantly improve students' understanding of concepts through consistent feedback, active student participation, continuous monitoring by teachers, and strengthening reflective thinking skills. In addition, this assessment assists students in correcting misconceptions, applying concepts in real contexts, and building learning independence. Meanwhile, Moreno-Ruiz et al. (2019), showed that the combination of flipped classroom learning, PjBL, and formative assessments has proven to be effective in deepening concept understanding. This strategy provides continuous feedback to students throughout the project, helping them recognize and correct misconceptions. Chanpet et al. (2020), also stated that online project learning equipped with formative assessments is able to encourage active involvement of students in solving problems and applying concepts in real life. Formative assessments play an important role in providing feedback that leads to a reduction in misconceptions and improved understanding of concepts. Therefore, formative assessments are a crucial part of the integration of project-based learning models through the Google Classroom platform.

A number of studies have been conducted on the use of Google classroom in PjBL, the implementation of Google classroom combined with formative assessment, and the combination of PjBL and formative assessment. One example is a study conducted by Moreno-Ruiz et al. (2019), A number of studies have been conducted on the use of Google classroom in PjBL, the implementation of Google classroom combined with formative assessment, and a combination of PjBL and formative assessment. One example is a study conducted by. Another study conducted by Chanpet et al. (2020), shows that the application of formative assessments in online project learning can increase student engagement, improve academic outcomes, and create a more interactive learning atmosphere. However, the study did not specifically develop interactive learning media that utilizes Google classroom with a focus on dynamic fluid materials and an in-depth exploration of the integration of formative assessment features as contained in this study. On the other hand, research conducted by Sari et al. (2019), states that formative assessments in the context of PjBL are very effective in encouraging continuous improvement, increasing student participation, providing opportunities for personalization of learning, and supporting the development of important skills through the feedback provided. In contrast to previous research, this study focuses on the development of interactive learning media that is integrated with Google classroom, equipped with special features designed to systematically strengthen the understanding of dynamic fluid concepts, as well as make formative assessment an important element in the design of these media. This research intends to support a more interactive and efficient learning strategy using Google classroom in PjBL accompanied by formative assessments to improve the understanding of dynamic fluid concepts for high school students.

METHOD

This research adopts a Research and Development (R&D) approach, which is a research method that focuses on the development process of a product, not to test a theory. In its implementation, the ADDIE development model is used which includes five main stages: Analyze, Design, Development, Implement, and Evaluate (Branch, 2009), with the evaluation stage carried out at each other stage, as illustrated in Figure 1.

The analysis stage was carried out to explore and determine the underlying needs for the development of PjBL-based interactive learning media that is integrated with the Google classroom platform. This analysis process refers to the learning outcomes in the Independent Curriculum for Physics class XI, especially on the topic of dynamic fluids. The analysis also involves the identification of student characteristics obtained through the implementation of pretests and observation results, which shows the need for learning media that is able to support the active, independent, and project-based learning process. The researcher conducted interviews with physics teachers to obtain information about various obstacles that arise in the learning process and to identify the need for interactive and accessible media. Evaluation of previously used media shows that most of them are still one-way and have not fully accommodated formative assessments. The findings from this analysis stage are used as a foundation for designing media structures, project-based learning syntax, and formative assessment instruments at the next stage of development.

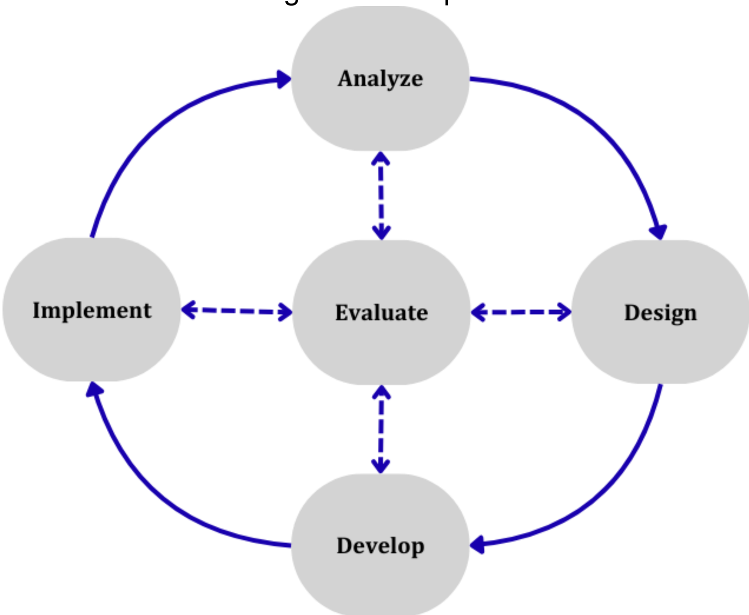

Figure 1. ADDIE Procedure

The design stage aims to compile the basic framework of the interactive learning media to be developed. In this stage, the researcher designed a media structure and workflow based on Google Classroom, which was further combined with the steps in the PjBL model. The designed media included materials on dynamic fluids, learning videos, discussion rooms, project-based assignments, and formative assessment quizzes, all of which were integrated into one platform to allow learning to take place in an integrated manner. In addition to designing media content, the researcher also compiled a set of research instruments that included product validation sheets (for validators of material and media experts), questionnaires of teacher and student responses (for practicality tests), and pretest and posttest questions (to measure media effectiveness). All instruments are compiled using the Likert scale and formatted in digital form through Google Form to facilitate the process of data distribution and analysis. As part of the evaluation design process, the researcher determines the indicators and assessment criteria used to assess the validity, practicality, and effectiveness aspects of learning media. The assessment is carried out quantitatively by analyzing the percentage of scores as well as through statistical testing. The results of this evaluation are the basis for making improvements and improvements to the media in the next stage. Therefore, the evaluation design made is not only a guide in the development process, but also the basis for the implementation of a comprehensive product evaluation.

This study uses a quasi-experimental design in the form of a pretest-posttest control group design. This design involves two groups, namely the experimental class that uses interactive learning media and the control class that does not use interactive learning media. In both groups, a pretest was given to determine the initial ability of students, then the experimental class was given treatment in the form of the use of interactive learning media, while the control class was not given treatment. After learning, both groups were given a posttest to determine the improvement in understanding of the concept of dynamic fluids. Thus, the difference in results between the pretest and posttest in both groups can be used to determine the effectiveness of the learning media developed.

The instruments used in this study include validation sheets of material experts and media experts, teacher and student response questionnaires, and pretest and posttest questions to measure the understanding of the concept of dynamic fluids. The validation sheet is used to assess the feasibility of the media in terms of content, appearance, interactivity, and suitability with learning objectives. Response questionnaires were used to measure the practicality of media based on the perception of teachers and students, while pretest and posttest questions were used to determine the improvement of concept understanding before and after learning. All instruments were arranged using a five-level Likert scale with a score range of 1 to 5, which consisted of the categories of very lacking, lacking, adequate, good, and very good.

The development stage aims to realize learning media based on a pre-designed design. At this stage, the researcher builds interactive media using the Google Classroom platform by integrating various components, such as dynamic fluid materials, learning videos, discussion forums, project worksheets, and formative assessment quizzes, which are arranged following the steps in the PjBL model. After the learning media has been developed, the next stage is validation carried out by two validators, namely material experts and media experts. This validation was carried out using an assessment instrument in the form of an evaluation sheet using a five-level Likert scale. This instrument assesses several aspects, including content quality, visual appearance, level of interactivity, and relevance of media to learning objectives. The validation data was then analyzed quantitatively descriptively to obtain the percentage of product validity level. The findings of this analysis are used as a basis for making improvements to the media before entering the implementation stage.

The implementation stage aims to test the extent to which the validated interactive learning media can be applied, by involving grade XI MIPA students as experimental subjects. Implementation activities were carried out with a quasi-experimental design, class XI-11 Science 3 as the experimental group and class XI-12 Science 4 as the control group. In addition to assessing the effectiveness, the researcher also evaluated how practical the media was by giving questionnaires to teachers and students after the media was used. This questionnaire contains questions regarding ease of access and use, interface design, clarity of material content, and students' active participation in project-based learning. The results of this test were obtained from a questionnaire filled out by teachers and students based on the Likert assessment scale. Meanwhile, the effectiveness of the media was evaluated by comparing the results of the students' pretest and posttest to see an increase in understanding of dynamic fluid materials. The data obtained at this stage is then analyzed using the data analysis techniques that have been set.

Research data was obtained through several stages that were carried out systematically. The first stage is to give a pretest to students to find out their initial abilities before learning. The second stage is the implementation of learning using interactive learning media in experimental classes, while the control class uses conventional learning. The third stage is the administration of posttests after learning to determine the improvement of students' understanding of concepts. In addition, data was also obtained through filling out response questionnaires by teachers and students to assess the practicality of the media, as well as through validation sheets filled out by material experts and media experts to assess the feasibility of the developed products.

The data analysis in this study was carried out quantitatively using descriptive and inferential techniques. Validity analysis was carried out by calculating the percentage of expert assessment score scores to determine the level of feasibility of learning media. The practicality analysis was carried out by calculating the percentage of the questionnaire score of teacher and student responses. Meanwhile, the effectiveness analysis was carried out through a statistical test using an independent t-test to determine the difference in learning outcomes between the experimental class and the control class. In addition, the improvement of students' conceptual understanding was analyzed using N-gain calculation (Hake, 1998). The

N-gain scores obtained were then classified into low, medium, and high categories to determine the level of improvement in students' conceptual understanding after learning.

$$N - \text{gain} = \frac{\text{skor posttest} - \text{skor pretest}}{\text{skor maksimal} - \text{skor pretest}}$$

RESULTS AND DISCUSSION

This study intends to design an interactive learning tool to answer various educational obstacles in today's digital era. Observations and interviews were conducted at SMA Negeri 2 Pare, which has implemented the Independent Curriculum in its learning. Grade XI Saintek students receive physics lessons for five hours per week divided into three days. The interview process is carried out directly through face-to-face meetings, both with teachers and students. The interview covers five aspects, namely the learning process, learning resources, learning media, media effectiveness, and input on the media used. These five aspects were then developed into Nine questions for teachers and nine questions for students. Follow-up observations were directed at interviews with physics teachers at schools. This research interview was conducted as a form of confirmation from the resource persons who were used to dig up information to complete the limited test results data with a questionnaire. This form of confirmation is used to support ongoing research. The interview that was held invited a physics teacher as the main speaker. This stage is the initial form of recognizing research problems. The activities carried out aim to identify various aspects of the problem, such as learning conditions, profiles of educational institutions, and needs analysis (Sugianti, 2020). Needs analysis is classified into two main aspects, namely the needs of the teacher and the needs of the students. The researcher carried out this activity to explore problems that occur in the context of education. This initial study was carried out when the researcher underwent Teaching Assistance (AM) activities in the seventh semester.

The results of interviews with teachers show that the way of teaching about dynamic fluid materials still uses the old approach, with the dominant lecture method and limited discussion. Teachers state that many students have difficulty understanding the material due to its non-concrete nature and lack of visual elements. This is also expressed by students, who feel that the learning process is less interesting due to the lack of activities that can make them actively involved. They tend to only act as passive listeners, which results in their low understanding of the material. In terms of learning resources, teachers still rely on package books, worksheets, and some resources from the internet such as YouTube videos. Although access to information is quite easy, both teachers and students state that the materials from these various sources are not well organized, making it difficult to use them as a comprehensive learning reference. For learning media, Google Classroom has been used, but its use is still limited to delivering materials and assignments. This media has not been maximized to create active and interactive learning.

Most students revealed that they were already quite familiar and comfortable when using Google classroom. However, they argue that the material provided is less interesting because it consists more of text or PDF files, which affects their understanding of the material and reduces their interest in learning. Teachers also realize that the use of digital media can be more optimal if presented in a more interactive format, which can increase student participation, such as with project-based learning methods. Research conducted by Setiyadi et al. (2024), supports this view by showing that the application of the PjBL model is significantly able to improve students' science process skills through involvement in active learning activities that are relevant to daily life. In addition, research conducted by Makrufi (2016), related to fluid dynamics material, shows that the PjBL method has a good influence on the learning outcomes of high school students, because it can help explain abstract concepts through more practical activities. Even Meo et al. (2024), emphasized that PjBL not only improves learning outcomes, but also contributes to the development of students' science literacy as a whole, including the understanding of concepts, processes, and applications in real situations.

As a form of input, teachers want the learning media developed to be flexible, in harmony with the curriculum, easily accessible and used by teachers and students, and able to accommodate various types of learning styles. On the other hand, students want learning media that is more interactive, not boring, and equipped with visual elements such as videos or simulations. They also expect opportunities to learn through hands-on activities or relevant projects. Based on the analysis conducted, it can be concluded that there is an important need to create interactive learning media, which can increase student engagement and strengthen their understanding, especially in materials related to dynamic fluids. Google classroom has a strong potential to be used as an interactive learning medium, especially when combined with the PjBL approach.

After the needs analysis stage is completed, the process continues to the design stage. At this stage, the researcher prepares a plan and initial design of interactive learning media to be developed. The design includes the determination of content structures, learning flows, and relevant media features, which are tailored to the characteristics of the students as well as the needs in understanding the concept of dynamic fluids. This design also refers to the syntax of the PjBL model which is integrated in the Google Classroom platform, so that the media produced is expected to be able to support an active and meaningful learning process. In the initial design process, basic competencies and achievement indicators are first determined. His main focus is the ability to analyze and present the concept of dynamic fluids and their application in everyday life. Learning objectives are formulated so that students are able to understand and apply these concepts through the implementation of projects that are systematically designed (Tain et al., 2024). The series of learning activities is systematically designed with reference to the steps in the PjBL model. Problem recognition, concept exploration, project development, presentation of results, and reflection (Tain et al., 2024). With this, the flow of the activity is visualized in the form of a flowchart in Figure 2.

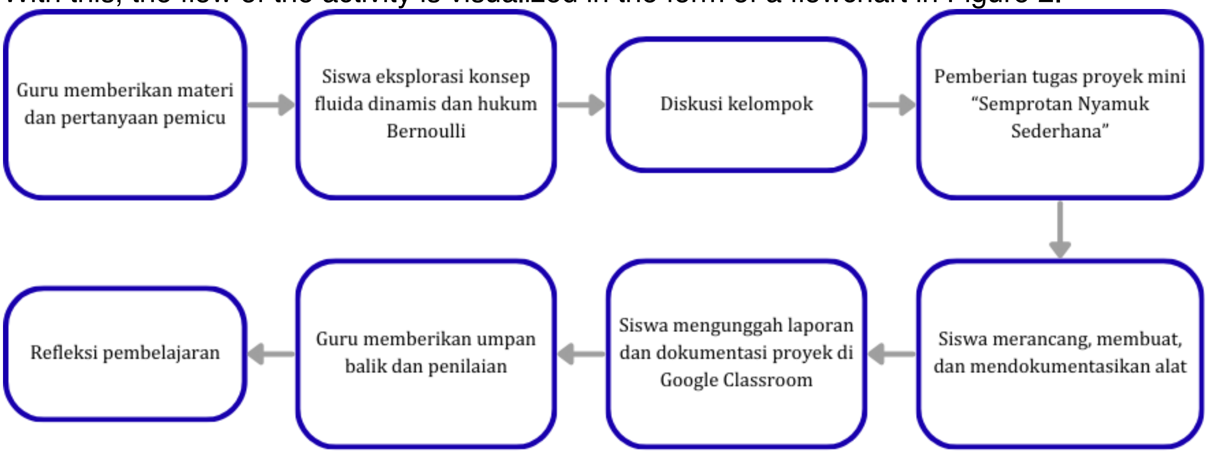

Figure 2. Flowchart Media

The material that has been validated is then processed at the product development stage. This learning media is based on the PjBL model which is integrated with the use of Google Classroom as the main media. The PjBL model was chosen because it is considered effective in increasing students' active involvement in the learning process, as well as encouraging them to independently or collaboratively seek information, understand concepts, and solve problems related to dynamic fluids (Čavić et al., 2023; Fahrunisa & Handayani, 2024). The form of implementation of this approach, the project raised in the learning is the creation of a simple tool in the form of mosquito spray, whose working principle is based on the concept of dynamic fluids, especially Bernoulli's law. Project-based learning with this kind of real task is able to awaken students' motivation and metacognitive awareness (Čavić et al., 2023). Learning media design utilizes various features available in Google Classroom which has proven to be an effective platform in project-based learning because it is flexible and familiar to students and teachers (Anis & Puspitasari, 2020). Virtual classes are designed to be easily accessible and usable with a systematic topic structure to facilitate navigation and learning. The layout and structure of the class display are divided into several main topics to make navigation and understanding easier.

The compiled media components include PDF material files, learning videos, infographics, simulation links (such as from PhET), Project Worksheets, Google Form-based quizzes, and discussion and reflection forums. Evaluation is carried out through quizzes, rubric-based projects, and reflection, as assessed in PjBL which emphasizes learning processes and products (Lestari et al., 2024). The learning media in the form of Google Classroom interactive media has been completed, then it will be integrated with links.

After designing the material, the material is validated by experts. Validators get a final score of 90%. The meaning of the number is to show that the material used is very valid. Therefore, the material that has been validated is worthy of proceeding to the next stage.

Media validation is carried out after the material validation process is completed, by involving competent lecturers as validators. The purpose of this validation step is to evaluate the extent to which the learning media made is qualified and valid before being applied to respondents. The results of the evaluation from media experts showed that the suitability rate reached 91.67%, which is in the very valid category. Thus, learning media that uses Google classroom and is intended for dynamic fluid materials and is connected to formative assessments is stated to be very appropriate to be used at the next stage of implementation. After it is proven valid for the materials and media used, a practicality test is carried out. Shows a percentage value of 75.64% which means that the product falls within the practical criteria to be applied and used in learning.

In the implementation, a limited trial of Google Classroom interactive media was carried out for dynamic fluid materials with formative assessments for students in grades XI-11 of SMA Negeri Pare. From the limited trial, data was obtained through pretest and posttest tests conducted by students. The results of the t-test [$p=0.00<$ Sig. 0.05] showed that there was a significant difference in student learning outcomes between the experimental group and the control group after the treatment was applied. Next, the N-Gain test was carried out. The N-Gain test is used to measure how far the understanding of the concept of dynamic fluids in students is before and after the treatment is given. This process is carried out by calculating the difference between the normalized pretest and posttest scores, so that it can show the success rate of the applied learning method. The results of the overall N-Gain calculation are shown in Table 1.

The low N-Gain value in the control group was due to the lack of active student involvement, lack of interactive media, absence of formative assessments, and conventional learning methods. This has an impact on the low improvement of concept understanding before and after learning, which at the same time shows that the treatment in the experimental group has a significant influence on improving students' conceptual understanding.

After seeing the results of the high conceptual understanding in the experimental group, the students also showed greater curiosity about the project they were working on. Several questions arise from students as a form of reflection and evaluation of the learning process they experience. For example, they question the reasons for using simple materials such as used bottles and straws, "Why should we use used bottles and straws? Can it really demonstrate the principle of dynamic fluids?", which shows their efforts to understand the function of materials in representing physical concepts in a concrete way. Other questions like, "In which part of this spray does Bernoulli's law occur? How can we know it really works?", reflecting their interest in directly relating parts of the tool to the theories that have been studied. In addition, students also ask technical questions related to the experiment, such as, "Why do we have to measure the height of the water level or the size of the spray hole? What is the effect on the outcome?", which shows that they are beginning to understand the role of variables in influencing the outcome of a project and their relationship to physical principles such as continuity and Torricelli. These questions not only show an increase in students' active participation, but also become an indicator that project-based learning facilitated through interactive media encourages them to think critically, understand concepts thoroughly, and relate them to real situations, so further study is needed on the factors that lead to the effectiveness of these learning media.

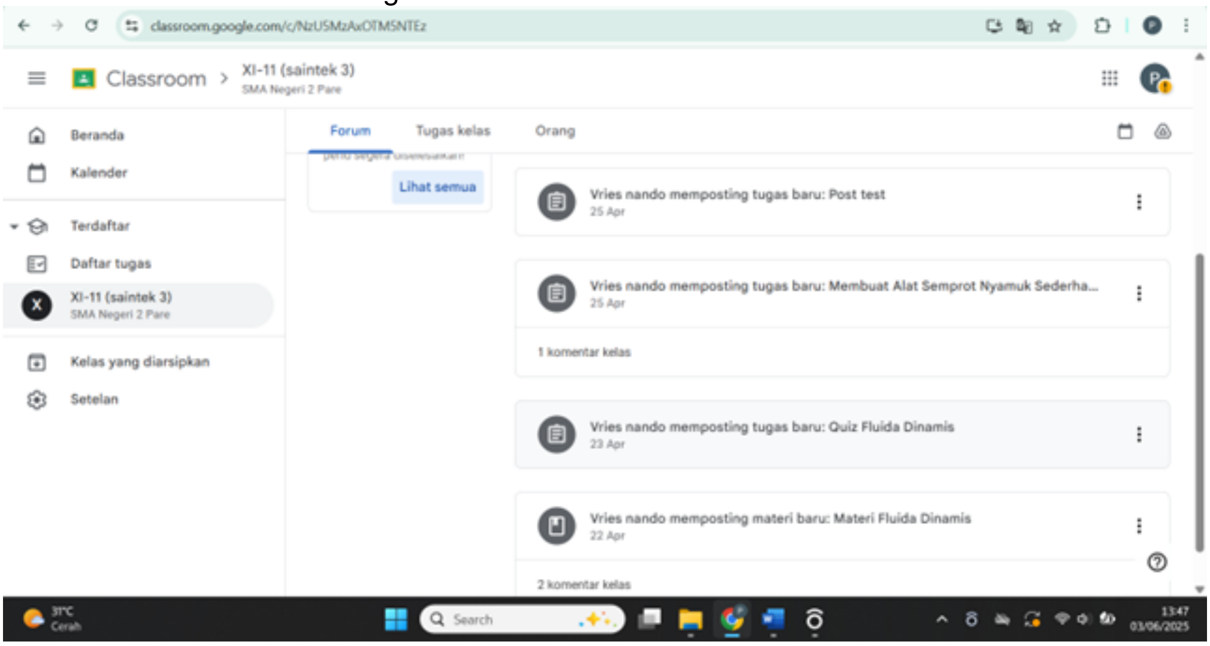

Figure 3. Google Classroom Media

Table 1. N-Gain Score of Control and Experiment Group

Group	N-Gain Average Scor (%)	Criteria
Control	30	Low
Experiment	74	High

The effectiveness of the learning media developed in this study is not only shown by the improvement of student learning outcomes, but can also be explained through the characteristics of the media that integrate the PjBL model with formative assessments in the Google Classroom platform. This is because the application of the PjBL model encourages students to be actively involved in the learning process through contextual project completion, so that the understanding of concepts becomes deeper and more meaningful. The use of projects can support students to see firsthand the relevance of projects in harmony with daily life (Ahmad et al., 2024). In addition, the use of Google Classroom provides easy access to learning materials, allows for more flexible interactions between teachers and students, and supports the sustainability of the learning process outside the classroom. Formative assessments integrated in the media also play an important role in providing direct feedback, so that students can identify errors and improve their understanding gradually. Thus, the combination of project-based learning, the use of digital technology, and the provision of continuous feedback are the main factors that cause this learning medium to be effective in improving the understanding of the concept of dynamic fluids.

CONCLUSION

Interactive learning media based on Google classroom and developed using the PjBL approach and formative assessments have proven to be very reliable, practical, and successful in improving the understanding of grade XI students about the concept of dynamic fluids. The results of the validation process showed that the media and materials were in the very valid category, with a percentage of 91.6%, while the effectiveness test showed a significant increase in concept understanding with a high category N-Gain score of 74%. The factors that cause the increase in understanding of the concept of dynamic fluids include active student involvement in working on projects, access to Google classroom that can be done anywhere and anytime, and feedback that teachers give to students on an ongoing basis. This learning strategy can be an alternative option for physics learning that is interactive and contextual, in accordance with the needs of the national curriculum. However, this research only covers the implementation of the concept of dynamic fluids, the use of the internet to download materials in Google classroom, and the need for more study time to support students to be actively involved in projects. Therefore, further research can be implemented on different physics concepts and using LMS or learning media similar to Google classroom that can be accessed and downloaded online or offline.

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