Kurdish Studies
Apr 2023
Volume: 11, No: 2, pp. 5165-5181
ISSN: 2051-4883 (Print) | ISSN 2051-4891 (Online)
www.KurdishStudies.net

Received: May 2023 Accepted: June 2023
DOI: https://doi.org/10.58262/ks.v11i2.374

Integrating Authentic Learning in Collaborative Problem-Solving Model: Stacking Analysis of Students' Problem-Solving Abilities

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Abstract

The problem-solving abilities and student collaboration in learning physics are still low, so meaningful learning is needed, namely through authentic learning. Appropriate teaching materials and models are needed to support students' academic achievement. This study aims to describe the feasibility of teaching materials that integrated authentic learning using collaborative problem-solving models in training students' problem-solving abilities. In developing teaching materials, research and development are used with the ASSURE model, which is strengthened by the use of stacking analysis to describe students' problem-solving abilities. The data analysis technique uses N-gain calculations and stacking analysis through the Winstep program. The results show that the validity of the developed teaching materials is measured using validation sheets by academic and practitioner validators with a validation value of 3.55 and categorized as very valid; The practicality of the teaching materials developed was measured using a student response questionnaire with a value of 2.86 and categorized as practical for use during the learning process; The effectiveness of the developed teaching materials was measured using a cognitive academic achievement test of students collaboratively with an N-gain of 0.73 and in the high category; The problem-solving skill of students collaboratively based on the learning achievement test which includes analytical questions is categorized as good. Therefore, it is concluded that the teaching materials developed are appropriate for use in the learning process to improve students' problem-solving abilities. Furthermore, the data from stacking analysis is used to get a deeper insight into students' problem-solving abilities, so that, in subsequent learning, the teacher can optimize the learning design to reach better students' academic achievement. Accordingly, implications and recommendations for future research were discussed at the end of this paper.

Keywords: *academic achievement, authentic learning, collaborative problem-solving, problem-solving abilities, stacking analysis*

Introduction

Learning within the scope of education is the foundation that determines the quality of the competence of students at every level. The competencies demanded in learning are always developing according to the demands of the times so it requires students to master them

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comprehensively. Learning around problem-solving can take place optimally when students are active and participate in the process. One of the main abilities that can support the problem-solving process is the skill to collaborate (Binkley et al., 2012; Segura et al., 2023; Sjöberg & Brooks, 2022). Thus, physics learning is expected to take place more optimally and students' abilities will increase through the processes they face together when solving problems.

Problem-solving has a significant influence on student performance and can trigger critical and creative thinking, stimulate students to think deeply and give students a greater ability to solve problems (Bunterm et al., 2012; Burkholder et al., 2021; Marham et al., 2021; Yalçın & Erden, 2021). Based on the results of an international assessment held by the Organization for Economic Cooperation and Development (OECD) using PISA questions, shows that Indonesian students are ranked 71st out of 79 countries in 2018. This fact reveals that Indonesian students' problem-solving abilities in science such as physics are still relatively low.

Mastery of the concept of physics in linear motion is the main obstacle for students to develop problem-solving abilities because of the abstract nature of the material, even though physics is a natural science that is closely related to everyday life and should be quite familiar with its authentic application. The relevance between the concepts studied and the cognitive development of students becomes a reference in building learning references that are effectively applied to learning (Choy & Yeung, 2022; Dunlosky et al., 2013). Therefore, learning resources should lead students to become more familiar with these physics concepts by providing teaching materials based on authentic learning.

Authentic learning is defined as a learning approach that orients students to discuss, construct, and develop knowledge in a meaningful way by linking the concepts learned with relevant problems or phenomena in their lives (Grube et al., 2022; Herrington et al., 2014; Ruhanen et al., 2021; Valtonen et al., 2015; West, 2023). Authenticity plays an important role in the future of various job sectors (Abbas et al., 2023; Rahmawati & Ladita, 2020). Thus, teaching materials become more effective to improve students' skills to solve problems.

This is because certain processes or stages must be completed to obtain a solution, both individually and in groups. Therefore, students also need to collaborate with their friends to enhcance their participation while honing their skills (Chen et al., 2023; Huang & Lajoie, 2023; Knickel, 2023; Mali et al., 2023; Muñoz et al., 2023; Yang, 2023). The solution to realizing this learning environment is to apply a collaborative problem-solving model (Dindar et al., 2020; Li et al., 2023; Sun et al., 2020; Wu et al., 2022). Collaborative problem-solving is interpreted as a collaboration-oriented learning model carried out by a group of students by sharing understanding and contributing to solving problems (Andrews-Todd & Forsyth, 2023; Avry et al., 2020; Dindar et al., 2022; Eiris et al., 2022; Felmer, 2023; Gao et al., 2022; Rojas, 2021; Song et al., 2022; Sum & Bădescu, 2023; Von Davier et al., 2017; Zhang, 2022).

This analysis is related to academic achievement which is expressed by increasing problem-solving abilities after using the teaching material. Improving the skill of students can be realized if the products developed can provide progress in achieving learning objectives (Nieveen & Folmer, 2013; Anna et al, 2023). Although a lot of research has been done on the impact of applying collaborative problem-solving to improve students' cognitive and interdependence in learning, (Swiecki, 2021; Wu et al., 2022), the implementation of authentic learning (Herrington et al., 2014; Irvine, 2022; Singer, 2020) and the development of learning and teaching materials based on authentic learning (Dolapcioglu, 2022; Wati, 2020), however, research that integrates authentic learning and collaborative problem-solving has never been done.

Therefore, this study aims to describe the feasibility of teaching materials that integrated authentic learning using collaborative problem-solving models in training students' problem-solving abilities. Ultimately, this research sought to add to existing literature and references by providing valuable empirical evidence and insights into the use and effectiveness of teaching materials in the specific wetland school environment.

Methodology

In developing teaching materials that integrate authentic learning with a collaborative problem-solving model, research and development are used with the ASSURE model. Data were collected through validity tests, practicality tests, and academic achievement tests, which is including students' problem-solving abilities. The data analysis technique uses the calculation of validity and reliability, the average score of students' responses, and N-gain calculations of pretest and post-test. Furthermore, stacking analysis through the Winstep program is used to get a deeper insight into students' problem-solving abilities, so that, in subsequent learning, the teacher can optimize the learning design to reach better students' academic achievement.

Analyze Learner

At the beginning of designing teaching materials, we determine that the students who are involved in this research are high school students who are on average aged 15 to 17 years and categorized in the formal operational stage. They already have the skill to think abstractly so that they can use their reasoning to solve problems logically even though they are still at a simple level. At this stage of development, students' skills to solve problems related to everyday life can be trained in the learning process. More specifically, these students are at a school in a wetland environment so that the authentic learning presented is as much as possible linked to local wisdom, so students can accept the principles of meaningful learning.

State Objectives

Linear motion is the most fundamental concept in mechanics and has sub-material specifications in the form of uniform linear motion, uniformly changing rectilinear motion, upward vertical motion, downward vertical motion, and free-fall motion. It has concepts that are easy to find in everyday life so the application of this concept can be observed directly by students. The main materials and concepts taught to students are based on the basic competencies that have been determined. The basic competence of this material is to analyze physical quantities in linear motion with constant speed (fixed) and linear motion with constant acceleration (fixed) along with their application in everyday life, for example, traffic safety; Presenting data and graphs of the experimental results of object motion to investigate the characteristics of linear motion with constant (fixed) speed and linear motion with constant (fixed) acceleration along with their physical meaning.

Select Methods, Media, and Materials

Teaching material is a set of materials or lesson substances that are arranged systematically in displaying the complete form of competence that will be mastered by students in learning activities. Teaching materials developed must be tested for feasibility to produce a quality product. The feasibility test of the development of teaching materials can be carried out in three stages, namely validity, practicality, and effectiveness tests.

(1) Validity, is a measure of the validity of a product obtained from a series of assessments before the product is taken to the field or applied in learning. The indicators used for the validation test are content feasibility, presentation feasibility, language feasibility, and graphic feasibility which are assessed directly by experts following the research field.

(2) Practicality, is an aspect that indicates the ease of use of a product. In the development of teaching materials, practicality tests can be in the form of questionnaires or response questionnaires to assessments by students on the implementation of teaching materials in teaching and learning activities.

(3) Effectiveness, is a measure of the academic achievement by students after using the developed product. Effectiveness testing can be done by measuring the increase in academic achievement or student activities, in terms of product academic achievement from learning achievement tests, and academic achievement from student worksheets (Aini et al., 2018).

Utilize Media and Materials

Three professional validators validated the product's validity utilizing a teaching material validation sheet. The theoretical validity of the instructional materials was examined in the study. This validity is based on an expert perspective or judgment, scrutinized in terms of content and constructions. Content validity is related to the suitability of a product's content and the theory that underpins it, whereas construct validity is engaged with the quality of the components and elements that build the product being developed. The results of the validation of the experts also calculated the reliability with Cronbach's Alpha equation.

Require Learner's Responses

Response questionnaires that valid and reliable were distributed to students via the Google form with a scale range of 1-4. This response questionnaire contains 20 statements in the form of positive and negative statements. Data from the responses of students are calculated to find the average score and compared it with the criteria. It can be declared practical if categorized as practical at least or get a score of more than 2.80 out of a maximum score of 4.00 in the range.

Evaluate and Revise

Measuring the effectiveness of this product was carried out by giving a cognitive test in the form of linear motion questions in the form of 8 essays to 12 groups of class X students from a high school in Banjarmasin for the 2021/2022 academic year. However, the test instrument must first be tested for validity by three expert validators to be able to accurately and validly measure students' abilities in determining the effectiveness of teaching materials.

After that, the data analysis technique uses *N-gain* $(< g >)$ to measure the effectiveness of teaching materials based on the average pretest and posttest scores. The normalized N-gain or gain score is calculated using equation (1) (Hake, 1998).

$$< g >= \frac{\langle S_f \rangle - \langle S_i \rangle}{100 - \langle S_i \rangle} \quad (1)$$

$\langle S_i \rangle$ is the average of *the pretest*; $\langle S_f \rangle$ is the average of the *posttest*. The results of the N-gain calculation are compared with the criteria stated in Table 1.

Table 1. N-Gain Criteria.

$< g >$ **Score**	Criteria
$(< g >) \geq 0.7$	High
$0{,}3 \leq (< g >) < 0.7$	Medium
$(< g >) < 0.3$	Low

The teaching materials developed can be declared effective if the N-gain (<g>) has the minimum criteria which mean the obtained score is more than or equal to 0.3.

The scores obtained from the academic achievement test for each group of students can be classified to determine problem-solving abilities on analytical questions. The assessment category for problem-solving abilities is stated in Table 2.

Table 2. Categories of Problem-Solving Abilities.

Score	Category
75-100	Excellent
50-74	Good
25-49	Fair
0-24	Poor

The test results for each group of students were also analyzed using the stacking technique through the Winstep program. The features of the Winstep program can present more accurate analysis results related to the impact of treatment on respondents (Yusuf & Widyaningsih, 2018). Data that is not an outlier will be detected by the Winstep program so that it can be analyzed based on the logit value (Bond et al., 2020).

Findings/Results

The development carried out in this study resulted in authentic learning-based linear motion teaching materials that could be applied using a collaborative problem-solving model. This teaching material is available as an electronic flipbook generated with the Flip PDF Corporate Edition application and can be accessed via the link provided by 000webhost.

The findings of the overall validity assessment of the teaching materials yield an average overall score of 3.55, with a very valid category. The development product that has been deemed valid means that its components have fulfilled the content and build standards of a quality product (Nieveen & Folmer, 2013). Furthermore, the findings of validators' assessments tend to be constant in every way, resulting in extremely good reliability calculations, with a score of 0.97. If a product's assessment yields consistent results, the assessment's findings do reflect the product's quality (Yudha et al., 2014). Thus, the generated teaching materials are ready to be used in the classroom.

Learner's Responses

Various recent learning innovations show that teachers in different types of classrooms can grow professionally by working with their students to understand classroom life and explore their classrooms, where teachers are the most important thing to focus on to improve learning processes. After the learning process, students fill out response questionnaires honestly and follow their respective opinions regarding the practicality of the teaching materials being developed as shown on Table 3.

Table 3. Students' Responses Towards Teaching Material's Practicality.

No	Aspect	Score	Category
1	Feasibility	2.83	Practical
2	Benefit	2.88	Practical
3	Efficiency	2.86	Practical
	Average	2.86	Practical

Students' Academic Achievement

Effectiveness is based on students' mastery and success in achieving learning objectives using the products developed (Nieveen & Folmer, 2013). The instrument used to measure this effectiveness is an essay consisting of 8 questions with cognitive levels C2 to C5. Academic Achievement tests were then distributed to 12 groups of students to obtain data on pretest values (initial test) before the application of treatment in the form of authentic learning-based linear motion teaching materials using collaborative problem-solving models.

The pretest and posttest assessment data were tested for normality first using SPSS 22 software via the Shapiro-Wilk test so that the pretest significance value was 0.154 and the posttest significance value was 0.553. Both have a significance value greater than 0.05 so the data are normally distributed. The data is then calculated using N-gain or normalized gain score to determine the effectiveness of using teaching materials as shown in Table 4.

Table 4. Results of the Effectiveness of Teaching Materials.

Average of ***Pretest***	Average of ***Posttest***	***N-gain***	**Category**
18.77	78.18	0.73	High

Based on the effectiveness measurement carried out, it is known that there is a significant increase in academic achievement so an N-gain of 0.73 is obtained in the high category. Therefore, authentic learning-based linear motion teaching materials using collaborative problem-solving models are effectively used in the learning process.

Student's Problem-Solving Abilities

Problem-solving abilities of students collaboratively can be measured through academic achievement tests which include analysis questions; C4 and C5. The solution also uses five stages which include problem visualization, problem description, planning solutions, implementing plans, and evaluating solutions (Heller et al., 1992). Problem-solving abilities based on the assessment of results on analytical questions are briefly summarized in Figure 1.

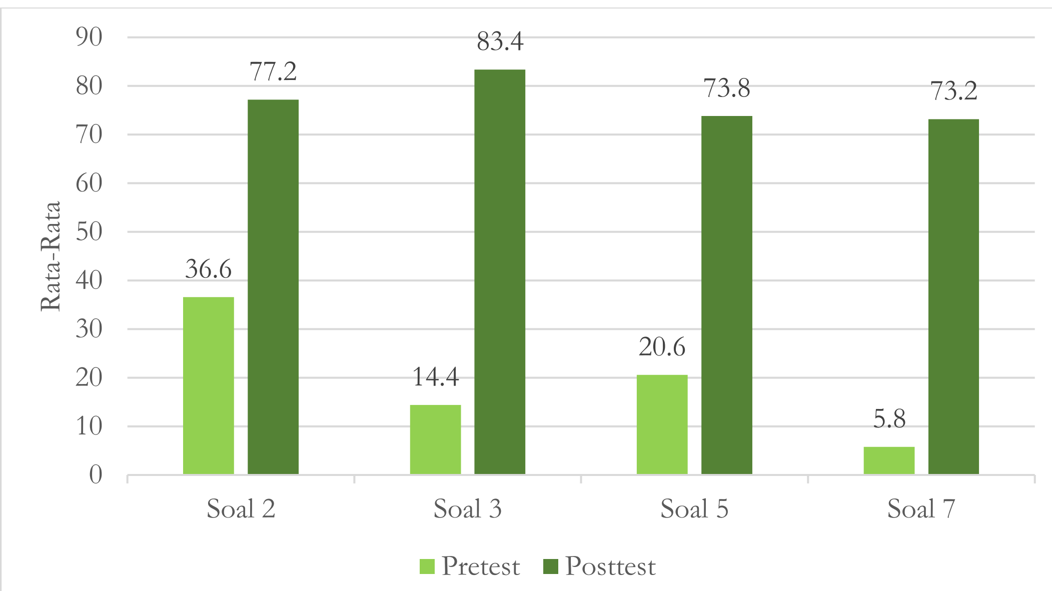

Figure 1. Problem-Solving Skill on Analysis Questions.

Problem-solving abilities can also be seen from the average score for each stage of problem-solving. A comparison of the average score between the pretest and posttest for each stage of the analysis questions can be seen in Figure 2.

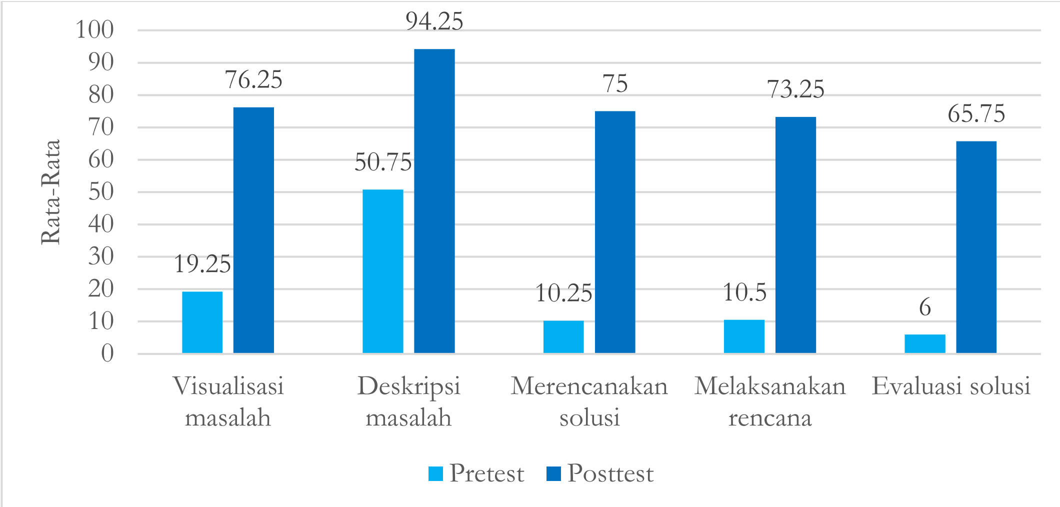

Figure 2. Problem-Solving Abilities for Each Stage of the Analysis Problem.

Stacking Analysis

The increase in the skill of each group of students can be analyzed further using the stacking analysis technique. Stacking analysis is part of Rasch modeling which is useful for analyzing interventions or changes in respondents' abilities at different times (Bond et al., 2020). That way, the increase or decrease in the skill of each group of students to solve problems can be known specifically through the scores obtained from the pretest and posttest. In the stacking analysis, the respondent's data and test scores are arranged vertically in a certain format so that they can be entered into the Winstep program. Data filtering has also been done previously and there are no outliers so all data can be used for stacking analysis. The data is then processed automatically to display the results through the variable (wright) maps feature. The results of data analysis on these features are presented in Figure 3.

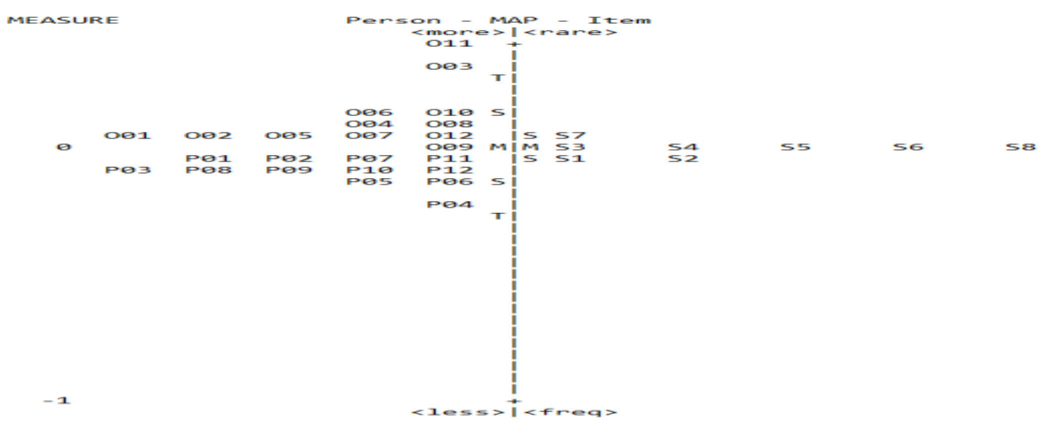

Figure 3. Display of Variable (Wright) Maps for Stacking Analysis.

The data on the left side of the variable scale line (wright) maps are persons or respondents consisting of 12 groups of students, while on the right it contains item data in the form of 8 items being tested. Stacking analysis is focused on changing the skill of respondents before and after being given treatment in the form of authentic learning-based linear motion teaching materials using collaborative problem-solving models. The identity of the respondent is represented by the code "P" for the skill during the pretest, while the skill during the posttest is represented by the code "O" and followed by the group number of each student. An increase in skill occurs if the position of the respondent during the posttest is higher than the initial position during the pretest, whereas if the position of the respondent during the posttest is lower than the position during the pretest then there is a decrease in skill after being given treatment. A summary of the size of the logit for each respondent is presented in Table 5.

Table 5. The Results of the Log Person from the Stacking Analysis.

Respondents	Logit *Pretest*	Logit *Posttest*	Logit Difference
Group 1	-0.05	0.02	0.07
Group 2	-0.05	0.04	0.09
Group 3	-0.08	0.22	0.30
Group 4	-0.15	0.08	0.23
Group 5	-0.11	0.05	0.16
Group 6	-0.11	0.11	0.22
Group 7	-0.03	0.03	0.06
Group 8	-0.06	0.07	0.13
Group 9	-0.06	0.01	0.07
Group 10	-0.07	0.09	0.16
Group 11	-0.05	0.28	0.33
Group 12	-0.06	0.03	0.09
Average	-0.07	0.09	0.16

The data set from the person measure shows a comparison of the logit pretest and posttest. Respondents who have a positive logit difference indicate a change in the form of an increase in skill, while a negative logit difference indicates a decrease in skill when working on a given item (Bond et al., 2020). All respondents in this study had logit differences which were positive thus each group of students experienced an increase in skill after undergoing treatment.

The largest logit difference belongs to group 11 which is also the respondent with the highest posttest logit. In addition, the logit obtained by group 11 during the posttest was also greater than the average. This is because each student in the group is active and can understand the material in a linear line along with the stages of problem-solving in a comprehensive manner. Improving problem-solving abilities like this is closely related to the positive impact of the treatment applied during the four learning meetings using the collaborative problem-solving model. The stages of problem-solving are trained through examples of questions contained in teaching materials. The foundation for achieving a complete understanding of these problems is reflected through authentic learning of physics concepts (Arsyad et al., 2020). That way, the teaching materials developed provide effective changes in the form of increasing the problem-solving abilities of each group of students.

Discussion

The quality of teaching materials with a highly valid category which means that the main components on learning materials are very well constructed. Flip PDF Corporate Edition as a material design program likewise supports format setting so the layout of the elements in the instructional materials are appropriate and appealing. The decent format's carrying capacity can foster students' interest in the teaching materials generated, allowing them to better regulate their attention to the learning process. Furthermore, the various color patterns make using these instructional materials more enticing to students.

The language aspect of the validity of the teaching materials is assessed as very valid. Since it is in line with students' progress, both in terms of the degree of thinking development and social-emotional development, the presentation of the content in it may be transmitted effectively.. The use of vocabulary used is not rigid, and it is conveyed in a dialogical manner through apperception, which can excite and urge people to think. All of those criteria also matched the Ministry of National Education's, linguistic requirements, which include meaning integrity, conformity to Indonesian language norms, grammar, and easily understandable messaging.

On the content side, the validity of the teaching materials is rated as very valid. This can be proven from symbols, terms, units, facts, and concepts that are accurate in describing the basic competencies of linear motion. The scope of the material is supported by a complete and in-depth discussion so that students can adjust the knowledge they have gained with the development of science. Example of phenomena in teaching material are relevant to students' situations and are backed up by current sources that are in line with today's learning needs.

The validity of teaching materials on the presentation aspect is categorized as very valid. The criteria are classified based on the presentation technique, presentation support, and learning presentation. Each chapter and sub-chapter is composed of consistent and balanced material from easy to complex subjects so that the concept of linear motion can be studied coherently. Authentic learning is also presented to connect abstract concepts in linear motion with real facts in the lives of students such as the movement of land transportation, *kelotok* or boats crossing rivers and lakes in a tourist attraction, fruit falling freely from the tree trunk, and ball motion in games of *bekel* ball. The existence of authentic learning makes the information presented by teaching materials more meaningful (Christmas, 2014). Physics learning will be more meaningful if learning facilities and references are taken from daily activities around the students' living environment (Arsyad et al., 2020).

To condense information efficiently, each chapter includes examples of real questions and debates to help students practice their collaborative problem-solving abilities. This linear motion teaching materials may be used in the learning process with a collaborative problem-solving approach, especially during the transformation phase. Through the "Let's Collaborate" section on real instances of questions that allow interactive dialogue to be developed, students become part of group discussions to solve problems based on the subjects learned in the teaching materials. Collaborative problem-solving was controllable and standardized, which can place students in a variety of different collaborative situations, as well as control test time (Trihantoyo et al., 2023; Ouyang et al., 2021; Tang et al., 2021). As a result, students will have a better understanding of their position in groups while working to solve problems based on the phases described in the instructional materials.

Starting with envisioning the problem and ending with assessing the solution, the examples of questions in the training materials depict the stages of problem-solving using the Heller indicators (Heller et al., 1992). As a result, problem-solving is practiced by using examples of questions from the training materials. Furthermore, these teaching materials include intriguing elements such as the "Let's Know" section, which offers material details, the "At a Glance Information" section, which contains valuable information to extend the gems of knowledge, and the "Magic Symbol" section, which contains a link to encourage students' interest Students' curiosity should be piqued by presenting them with engaging educational resources.

Based on benefits/usability, the validity of the teaching materials is rated as very valid. This is interpreted to mean that the teaching resources developed can help teachers teach the notion of linear motion authentically (Aswinna & Rahmi, 2021). This authentic learning-based linear motion teaching material can be utilized as a resource for students to study independently and discuss in groups to fully comprehend the contents. As a result, these teaching materials promote learner-centered learning while reducing reliance on teachers.

The results obtained from the assessment in each aspect of its validity determine the quality of the teaching materials developed. Assessment is an integral part and an effective way of receiving feedback on students' learning outcomes (Singh & Chand, 2010). Validity is one of the eligibility criteria for product development (Nieveen & Folmer, 2013). The teaching materials developed in this study have been categorized as very valid according to experts. Therefore, these teaching materials can be tested on students through classroom learning.

On the other hand as shown on Table 4, the results of student responses in all aspects gave an average score of 2.86 in the practical category. The practicality of a development product expresses its ease when implemented in the desired learning environment (Nieveen & Folmer, 2013). Thus, the teaching materials developed are practical to be applied in learning process.

The quality of teaching materials can be described in more detail through aspects that support their practicality. In the aspect of ease of use, the results obtained are in the very practical category. The teaching materials developed are relatively easy to use because the contents of the material can be understood properly and the language used is following the needs and development of students. The design of teaching materials is also attractive and accompanied by authentic illustrations so that students have no difficulty identifying the meaning of these illustrations. This can be seen from the cover design which represents various phenomena of rectilinear motion in everyday life. In addition, this teaching material has clear instructions on the stages of problem-solving through authentic questions in it. The discussion is also supported by illustrations that are relevant to the conditions surrounding the students so that the concepts contained in the linear motion material become easy for them to learn.

The ease of use of this teaching material is inseparable from the meaningful information contained in it (Christmas, 2014). Learning becomes more meaningful if new information or concept in teaching material is linked to the cognitive structure of students. Information like this can be found in interesting features in the form of pop-ups such as "let's know", "at a glance", and "magic symbol" icons. The existence of pop-ups allows content in teaching materials to be displayed elegantly without taking up many pages. That way, the content presented is not monotonous in the form of writing and it is easier for students to use the features contained in the teaching material. The form of teaching materials in the form of electronic media also makes these interactive features economically available. Even so, the practicality of accessing the sub-material in the next chapter is still not optimal because no feature is designed to short access to certain pages automatically. Students still need to flip through the pages of this teaching material to arrive at the page in the new sub-chapter.

The practicality of teaching materials on the benefit aspect is categorized as practical. This shows that the teaching materials developed to provide benefits because they help students understand physics problems, encourage them to visualize linear motion problems through pictures/sketches, and attract their attention to learning through authentic illustrations.

This teaching material can be used by students to actively discuss with their group members in understanding and solving physics problems during learning using the collaborative problem-solving model, especially in the transformation phase. Students in this phase can collaborate in their respective groups to learn the stages of problem-solving described in the "let's collaborate" session in the teaching material. The sample questions in the session describe the stages of problem-solving using the Heller indicators (Heller et al., 1992), namely starting from visualizing the problem to evaluating solutions. In addition, the majority of students' responses also stated that authentic learning-based linear motion teaching materials were able to practice their collaborative problem-solving.

The last aspect relates to time efficiency in using teaching materials that categorized as practical. The teaching and learning process in class can be completed on time by using the developed teaching materials. This is evidenced by the majority of the results of student responses which stated that there was sufficient time to collaborate and re-examine the answers to the results of their discussions. Students who collaborate effectively can use their time efficiently. The concept of linear motion that is translated from teaching materials based on authentic learning can be understood more quickly by students, so it supports time efficiency during teaching and learning activities using the collaborative problem-solving model.

The results obtained from student responses in every aspect of their practicality determine the quality of teaching materials when applied in class. Teaching material is declared practical if the assessment obtained from the student response questionnaire gives an average score that is at least in the practical category. Practical teaching materials can be implemented in real terms in class and have a positive influence on students. This positive influence refers to the condition of teaching materials that are easy to use so that learning becomes more interesting, meaningful, and useful. Therefore, this teaching material can be used in the learning process in class.

Based on figure 1 and figure 2, at first, the pretest average was still very low because students in each group did not understand the stages of problem-solving in linear motion questions. They are also not used to collaborating to solve problems with their respective groups so they have difficulty sharing roles in doing the test. After the pretest, students are given treatment in learning in the form of authentic learning-based linear motion teaching materials and gain more comprehensive knowledge if they are involved in intensive interactions with their groups (Ouyang et al., 2021). The interactions and collaborations that occur have a major influence on building their engagement when discussing solutions to a problem (Ramirez, 2021; Utami & Hwang, 2022).

The average score in the posttest has increased significantly compared to the pretest, as evidenced by the high gain score. Even so, there were still students who had difficulty collaborating to complete the test with their group mates. This was because the students in this study had just entered grade X, so some of them tended to be unfamiliar and seemed awkward in communicating. Students who are less able to adapt when collaborating will find it difficult to solve problems. On the other hand, groups whose members actively collaborate experience increased abilities at a high level and can use the problem-solving stages well during the posttest. This increase is inseparable from the role of authentic learning-based linear motion teaching materials along with examples of authentic questions contained therein. The process of solving the problem is described in full in stages in the example questions in the teaching materials and is always practiced at each meeting. This is supported by a collaborative problem-solving model which also trains students to get used to collaborating to solve problems. Therefore, they finally became more prepared for the posttest and obtained optimal results.

Figure 1 shows students' abilities were still low because the problem-solving answers for questions number 2 and 5 resulted in an average score in the poor category, while the average value in numbers 3 and 7 was in the very poor category. Students in each group did not understand the concept and how to solve problems on the topic of linear motion so there were questions that were not answered. Lack of mastery of the material being studied will harm academic achievement. In addition, they are still confused when discussing because they have not found an effective way to share tasks and roles.

During the posttest, problem-solving abilities increased because the average score in each question was significantly higher than in the pretest. The answers to questions number 2, 5, and 7 produce an average score that is in the good category, while the average score in number 3 has reached the very good category. This significant increase is inseparable from the benefits of the authentic learning-based linear motion teaching materials that they have learned. Authentic learning can improve problem-solving abilities, and helps instill knowledge into the minds of students through phenomena in life to strengthen mastery of the material being studied (Christmas, 2014). The collaborative problem-solving model also plays a role fort students to collaborate with their groups so that they are more compact when working on the posttest. Therefore, their problem-solving abilities were able to reach a good category based on the average overall score on the analytical questions obtained from the posttest, which was 78.18.

The average pretest score for each stage is not categorized as good so it can be stated that students' problem-solving abilities are still low. They are less able to solve problems systematically, have difficulty digesting the essence of the questions, and are constrained in using the right concepts to solve problems (Markawi, 2015). Meanwhile, the average score has increased in the posttest with an acquisition above 60 so there are indicators that are categorized as good or very good based on the solutions given.

Completion at the stages of problem visualization, planning solutions, implementing plans, and evaluating solutions is categorized as good; while the problem description stage has been able to be resolved with a very good category. Each group of students has been able to represent physics problems visually to be translated into the form of physics concepts and equations systematically. The systematic settlement process and collaboration led them to get a real solution (Goh, 2014; Setlhodi, 2020; Suhandiah et al, 2022). The success of students in completing the stages of each problem increases the average post-test score. The overall average post-test score at the problem-solving stage gave a result of 78.18 which was as good as the results obtained based on the review of the questions. So, students' problem-solving abilities collaboratively on analytical questions are included in the good category.

Figure 3 shown by the variable (wright) maps, it is known that there are six groups of students (O11, O03, O06, O10, O04, and O08) who have a high skill to solve all items and their position on the scale line increases compared to the pretest position. The six respondents found it easier to do the tests given, as shown by their position which exceeded or was above all the item questions, thus proving that the treatment given worked well. The respondents in the following positions (O01, O02, O05, O07, O12, and O09) also experienced an increase in their abilities after being given treatment, even though most of their positions were parallel to the item items. Meanwhile, some respondents are in group 9 (O09) and are still under the position of one of the items as well as being the person with the lowest level. Such a position indicates that group 9 is the respondent with the lowest skill compared to the other groups.

Students in group 9 experienced a little difficulty when collaborating to solve problems from the questions given because their mastery of linear motion material was still not comprehensive.

This is because these students are less active and enthusiastic when undergoing learning using the teaching materials developed. The group cooperation was also not very compact. Those who are not cohesive in collaborating will find it difficult to solve problems together (Andrews-Todd & Forsyth, 2023; Dindar et al., 2022; Han et al., 2023; Rojas, 2021). Even so, the skill of each group of students in general still experienced an increase in solving questions on the academic achievement test. These increases are shown from their various positions or levels on the scale line which are affected by the logit magnitude.

Conclusion

Based on the evaluation of the development of teaching materials, test results, and findings obtained, it can be concluded that authentic learning-based linear motion teaching materials using collaborative problem-solving models are appropriate for use in the learning process because they meet the criteria to be declared valid, practical, and effective. This is expected to provide alternative learning materials that can help students understand the material and train the skills to collaborate in solving problems. This study contributes as an option for teachers to be able to use the teaching materials that have been produced. However, this study is limited to linear motion teaching materials only. In addition, the subject of this study is still limited to 12 groups with an average age of 15-17 years, it is hoped that other researchers can further enrich their studies both in terms of the teaching materials developed and the involvement of a wider subject. Based on the stacking analysis that we have presented in this study, we hope that future researchers can focus more on certain aspects of students' problem-solving abilities which are considered to be still able to be improved.

Limitations

Researchers are aware that there are several weaknesses and obstacles that occur when carrying out school research. The weaknesses and constraints are as follows. (1) The time for physics lessons is limited, namely only 60 minutes because of the rules applied during online learning. This affects the time management that researchers must pay attention to during the learning process. In addition, students need adjustments in following a short learning time using the collaborative problem solving model. This model requires adequate time for students to discuss. (2) Students who are the subject of the trial are new students who do not know each other intimately. This slightly affects the intensity of their communication when discussing and collaborating in solving problems.

References

Abbas, A., Ekowati, D., & Anwar, A. (2023). Authentic leadership journey: An empirical discussion from Pakistani higher education employing the lay theory of psychology. *International Journal of Public Leadership*. https://doi.org/10.1108/IJPL-04-2022-0020

Aini, N., Zainuddin, Z., & Mahardika, A. I. (2018). Pengembangan Materi Ajar IPA Menggunakan Model Pembelajaran Kooperatif Berorientasi Lingkungan Lahan Basah. *Berkala Ilmiah Pendidikan Fisika*, *6*(2), 264–277.

Andrews-Todd, J., & Forsyth, C. M. (2023). Assessment of collaborative problem solving skills. *International Encyclopedia of Education: Fourth Edition*, 494–503. https://doi.org/10.1016/B978-0-12-818630-5.10062-4

Anna, N.E.V., Kaur, K., & Yanti Idaya A.M.K. (2023). Teaching strategies for library instruction: directions from the literature . Malaysian Journal of Library and Information Science, 28(2), 63–87. https://doi.org/10.22452/mjlis.vol28no2.4

Arsyad, Z., Wati, M., & Suyidno, S. (2020). The effectiveness of the module static fluid with authentic learning to train students' problem-solving skills. *SEJ (Science Education Journal)*, *4*(2), 113–128.

Aswinna, A., & Rahmi, R. (2021). Use of Electronic Resources Before and During the Pandemic in the Universitas Indonesia Library. Record and Library Journal, 7(2), 215–227. https://doi.org/10.20473/rlj.v7i2.193

Avry, S., Chanel, G., Bétrancourt, M., & Molinari, G. (2020). Achievement appraisals, emotions and socio-cognitive processes: How they interplay in collaborative problem-solving? *Comput Human Behav*, *107*, 106267. https://doi.org/10.1016/J.CHB.2020.106267

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining twenty-first century skills. In *Assessment and teaching of 21st century skills* (pp. 17–66). Springer.

Bond, T. G., Yan, Z., & Heene, M. (2020). *Applying the rasch model: Fundamental measurement in the human sciences*. Routledge.

Boone, W. J., Staver, J. R., & Yale, M. S. (2014). *Rasch analysis in the human sciences*. Springer.

Bunterm, T., Wattanathorn, J., Vangpoomyai, P., & Muchimapura, S. (2012). Impact of open inquiry in science education on working memory, saliva cortisol and problem solving skill. *Procedia-Social and Behavioral Sciences*, *46*, 5387–5391. https://doi.org/10.1016/j.sbspro.2012.06.444

Burkholder, E., Hwang, L., & Wieman, C. (2021). Evaluating the problem-solving skills of graduating chemical engineering students. *Education for Chemical Engineers*, *34*, 68–77. https://doi.org/10.1016/J.ECE.2020.11.006

Chen, C.-J., Tsai, H.-J., Lee, M.-Y., Chen, Y.-C., & Huang, S.-M. (2023). Effect of a Moodle-based E-learning environment on E-collaborative learning, perceived satisfaction, and study achievement among nursing students. *Nurse Educ Today*, 105921. https://doi.org/10.1016/J.NEDT.2023.105921

Choy, M. W., & Yeung, A. S. (2022). Cognitive and affective academic self-concepts: Which predicts vocational education student's career choice? *International Journal of Educational Research Open*, *3*, 100123. https://doi.org/10.1016/J.IJEDRO.2022.100123

Christmas, D. (2014). Authentic pedagogy: Implications for education. *European Journal of Research and Reflection in Educational Sciences*, *2*(4), 51–57.

Dindar, M., Järvelä, S., & Järvenoja, H. (2020). Interplay of metacognitive experiences and performance in collaborative problem solving. *Comput Educ*, *154*, 103922. https://doi.org/10.1016/J.COMPEDU.2020.103922

Dindar, M., Järvelä, S., Nguyen, A., Haataja, E., & Çini, A. (2022). Detecting shared physiological arousal events in collaborative problem solving. *Contemp Educ Psycol*, *69*, 102050. https://doi.org/10.1016/J.CEDPSYCH.2022.102050

Dolapcioglu, S. (2022). Development of critical thinking in mathematics classes via authentic learning: An action research. *International Journal of Mathematical Education in Science and Technology*, *53*(6), 1363–1386. https://doi.org/10.1080/0020739X.2020.1819573

Dunlosky, J., Rawson, K. A., Marsh, E. J., Nathan, M. J., & Willingham, D. T. (2013). Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology. *Psychological Science in the Public Interest*, *14*(1), 4–58.

Eiris, R., Wen, J., & Gheisari, M. (2022). iVisit-Collaborate: Collaborative problem-solving in multiuser 360-degree panoramic site visits. *Comput Educ*, *177*, 104365. https://doi.org/10.1016/J.COMPEDU.2021.104365

Felmer, P. (2023). Collaborative problem-solving in mathematics. *Curr Opin Behav Sci*, *52*, 101296. https://doi.org/10.1016/J.COBEHA.2023.101296

Gao, Q., Zhang, S., Cai, Z., Liu, K., Hui, N., & Tong, M. (2022). Understanding student teachers' collaborative problem solving competency: Insights from process data and multidimensional item response theory. *Think Skills Creat*, *45*, 101097. https://doi.org/10.1016/J.TSC.2022.101097

Goh, K. (2014). What good teachers do to promote effective student learning in a problem-based learning environment. *Australian Journal of Educational and Developmental Psychology*, *14*, 159–166.

Grube, T., Scholtz, S., & Dorney, P. (2022). Authentic learning: Pedagogical approach to promote cognitive realism in a virtual environment. *Teaching and Learning in Nursing*, *17*(4), 446–448. https://doi.org/10.1016/J.TELN.2022.05.003

Hake, R. (1998). Analyzing change/gain scores: Measurement and research methodology. *American Research Association's Division*, *5*(2).

Han, A., Krieger, F., & Greiff, S. (2023). Assessment of collaborative problem-solving: Past achievements and current challenges. *International Encyclopedia of Education: Fourth Edition*, 234–244. https://doi.org/10.1016/B978-0-12-818630-5.09041-2

Heller, P., Keith, R., & Anderson, S. (1992). Teaching problem solving through cooperative grouping. Part 1: Group versus individual problem solving. *Am J Phys*, *60*(7), 627–636.

Herrington, J., Parker, J., & Boase-Jelinek, D. (2014). Connected authentic learning: Reflection and intentional learning. *Australian Journal of Education*, *58*(1), 23–35. https://doi.org/10.1177/0004944113517830

Huang, X., & Lajoie, S. P. (2023). Social emotional interaction in collaborative learning: Why it matters and how can we measure it? *Social Sciences & Humanities Open*, *7*(1), 100447. https://doi.org/10.1016/J.SSAHO.2023.100447

Irvine, K. (2022). A multidisciplinary approach to authentic learning experiences for nature-based solutions design: Broadening the monkey cheeks. *Australasian Journal of Engineering Education*, *27*(1), 47–63. https://doi.org/10.1080/22054952.2022.2083789

Knickel, M. (2023). Lost in a haze or playing to partners' strengths? Learning to collaborate in three transdisciplinary European living labs. *Futures*, *152*, 103219. https://doi.org/10.1016/J.FUTURES.2023.103219

Li, S., Pöysä-Tarhonen, J., & Häkkinen, P. (2023). Students' collaboration dispositions across diverse skills of collaborative problem solving in a computer-based assessment environment. *Computer in Human Behavior Reports*, *11*, 100312. https://doi.org/10.1016/J.CHBR.2023.100312

Mali, D., Lim, H.-J., Roberts, M., & El Fakir, A. (2023). An analysis on how a collaborative teaching intervention can impact student mental health in a blended learning environment. *The International Journal of Management Education*, *21*(3), 100853. https://doi.org/10.1016/J.IJME.2023.100853

Marham, M. A., Ibrahim, A. H., Yerizon, M. F. N., Abdullah, L., Jamaan, E. Z., & Mustaffa, N. (2021). A proposed conceptual framework for conducting problem posing intervention in a classroom (article). *Review of International Geographical Education Online*, *11*(4), 873–880.

Markawi, N. (2015). Pengaruh keterampilan proses sains, penalaran, dan pemecahan masalah terhadap hasil belajar fisika. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, *3*(1), 11–25.

Muñoz, M. J. P., Simón, de B. C., Anguita, R. F., & García, S. A. E. (2023). Collaborative learning in management subjects to university students: A multi-level research to identify group profile. *The International Journal of Management Education*, *21*(1), 100762. https://doi.org/10.1016/J.IJME.2022.100762

Nieveen, N., & Folmer, E. (2013). Formative evaluation in educational design research. In *Educational Design Research* (pp. 152–169). SLO.

Ouyang, F., Chen, Z., Cheng, M., Tang, Z., & Su, C.-Y. (2021). Exploring the effect of three scaffoldings on the collaborative problem solving processes in China's higher education. *International Journal of Educational Technology in Higher Education*, *18*(35), 1–22.

Rahmawati, D., & Ladita, N. (2020). Authentic leadership role on organizational innovativeness with creativity and organizational trust. *Opcion*, *36*(26), 1746–1763.

Ramirez, H. J. M. (2021). Facilitating computer-supported collaborative learning with question-asking scripting activity and its effects on students' conceptual understanding and critical thinking in science. *International Journal of Innovation in Science and Mathematics Education*, *29*(1), 31–45.

Rojas, M. (2021). Assessing collaborative problem-solving skills among elementary school students. *Comput Educ*, *175*, 104313. https://doi.org/10.1016/J.COMPEDU.2021.104313

Ruhanen, L., Axelsen, M., & Bowles, L. (2021). Engaging students through authentic learning: Connecting with international tourism partners. *J Hosp Leis Sport Tour Educ*, *29*, 100291. https://doi.org/10.1016/J.JHLSTE.2020.100291

Segura, C., Ferrando, I., & Albarracin, L. (2023). Does collaborative and experiential work influence the solution of real-context estimation problems? A study with prospective teachers. *The Journal of Mathematical Behavior*, *70*, 101040. https://doi.org/10.1016/J.JMATHB.2023.101040

Setlhodi, I. I. (2020). Collaboration practices between the two tiers of school leadership in eradicating underperformance. *S Afr J Educ*, *40*(3), 1–11.

Singer, A. (2020). How to foster the formation of STEM identity: Studying diversity in an authentic learning environment. *International Journal of STEM Education*, *7*(1). https://doi.org/10.1186/s40594-020-00254-z

Singh, S. V., & Chand, S. P. (2010). Effects of the examination-driven education system on teachers and students in primary schools in Fiji. *The International Journal of Assessment and Evaluation*, *29*(1), 102–117.

Sjöberg, J., & Brooks, E. (2022). Collaborative interactions in problem-solving activities: School children's orientations while developing digital game designs using smart mobile technology. *Int J Child Comput Interact*, *33*, 100456. https://doi.org/10.1016/J.IJCCI.2022.100456

Song, Y., Cao, J., Yang, Y., & Looi, C. K. (2022). Mapping primary students' mobile collaborative inquiry-based learning behaviours in science collaborative problem solving via learning analytics. *Int J Educ Res*, *114*, 101992. https://doi.org/10.1016/J.IJER.2022.101992

Suhandiah, S., Suhariadi, F., Yulianti, P., Wardani, R., & Muliatie, Y. (2022). Online learning satisfaction in higher education: what are the determining factors? Jurnal Cakrawala Pendidikan, 41(2), 351-364. doi:https://doi.org/10.21831/cp.v41i2.35724

Sum, P. E., & Bădescu, G. (2023). Collaboration and socio-economic inequality: Estimating the effects of intra-school and inter-school inequality on collaborative problem-solving skills. *Int J Educ Dev*, *102*, 102843. https://doi.org/10.1016/J.IJEDUDEV.2023.102843

Sun, C., Shute, V. J., Stewart, A., Yonehiro, J., Duran, N., & D'Mello, S. (2020). Towards a generalized competency model of collaborative problem solving. *Comput Educ*, *143*, 103672. https://doi.org/10.1016/J.COMPEDU.2019.103672

Swiecki, Z. (2021). Measuring the impact of interdependence on individuals during collaborative problem-solving. *Journal of Learning Analytics*, *8*(1), 75–94. https://doi.org/10.18608/JLA.2021.7240

Tang, P., Liu, H., & Wen, H. (2021). Factors predicting collaborative problem solving: Based on the data from PISA 2015. *Front Educ (Lausanne)*, *6*, 1–10. https://doi.org/10.3389/feduc.2021.619450

Trihantoyo, S., Herachwati, N., Purwono, R., Supriharyanti, E., & Aldhi, I.F.(2023). Experiential Learning And Collaborative Leadership: Moderating Effect Of Learning Climate In Emancipated Learning Program. *Malaysian Online Journal of Educational Management,* Vol. 11, No. 4.

Utami, I.Q., Hwang, WY. (2022). The impact of collaborative problem posing and solving with ubiquitous-decimal app in authentic contexts on math learning. J. Comput. Educ. 9, 427–454 https://doi.org/10.1007/s40692-021-00209-5

Valtonen, T., Kukkonen, J., Kontkanen, S., Sormunen, K., Dillon, P., & Sointu, E. (2015). The impact of authentic learning experiences with ICT for teaching and learning. *Comput Educ*, *81*, 49–58. https://doi.org/10.1016/J.COMPEDU.2014.09.008

Von Davier, M., He, Q., Samuel, G., Steinhauer, E. W., & Borysewicz, P. B. (2017). Collaborative problem solving measures in the Programme for International Student Assessment (PISA). *Innovative Assessment of Collaboration*, 95–111.

Wati, M. (2020). Developing of physics teaching materials based on authentic learning to train problem-solving skills. *Journal of Physics: Conference Series*, *1567*(3). https://doi.org/10.1088/1742-6596/1567/3/032084

West, J. (2023). Utilizing Bloom's taxonomy and authentic learning principles to promote preservice teacher's pedagogical content knowledge. *Social Sciences & Humanities Open*, *8*(1), 100620. https://doi.org/10.1016/J.SSAHO.2023.100620

Wu, Y., Zhao, B., Wei, B., & Li, Y. (2022). Cultural or economic factors? Which matters more for collaborative problem-solving skills: Evidence from 31 countries. *Pers Individ Dif*, *190*, 111497. https://doi.org/10.1016/J.PAID.2021.111497

Yalçın, V., & Erden, Ş. (2021). The effect of STEM activities prepared according to the design thinking model on preschool chidren's creativity and problem-solving skills. *Think Skills Creat*, *41*, 100864. https://doi.org/10.1016/J.TSC.2021.100864

Yang, X. (2023). Creating learning personas for collaborative learning in higher education: A Q methodology approach. *International Journal of Educational Research Open*, *4*, 100250. https://doi.org/10.1016/J.IJEDRO.2023.100250

Yudha, R. P., Masrukan, M., & Djuniadi, D. (2014). Pengembangan instrumen asesmen otentik unjuk kerja materi bangun ruang di sekolah dasar. *Journal of Educational Research and Evaluation*, *3*(2), 62–67.

Yusuf, I., & Widyaningsih, S. W. (2018). Implementasi pembelajaran fisika berbasis laboratorium virtual terhadap keterampilan proses sains dan persepsi mahasiswa. *Berkala Ilmiah Pendidikan Fisika*, *6*(1), 18–28.

Zhang, S. (2022). Understanding student teachers' collaborative problem solving: Insights from an epistemic network analysis (ENA). *Comput Educ*, *183*, 104485. https://doi.org/10.1016/J.COMPEDU.2022.104485