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Development of Assessment for Learning-Based Student Activity Sheets to Enhance Students' Problem-Solving Skills on Buffer Solution Topics

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Abstract: Problem-solving skills are important skills that need to be developed in chemistry learning, especially in buffer materials that are abstract and complex. However, the results of preliminary studies show that students' problem-solving skills are still relatively lacking. This research aims to develop Student Activity Sheets (LKS) with an Assessment for Learning (AfL) approach on valid, practical, and effective buffer solution materials to practice problem-solving skills. This research uses the Research and Development (R&D) method with a 4-D model which is modified into a 3-D model, limited to the define, design, and develop stages. The limited trial was carried out on 27 phase F students of SMA Hang Tuah 1 Surabaya using a one-group pretest-posttest design. The results showed that LKS obtained an average validity score of 4.27 with a valid category. The practicality of the LKS is shown by the percentage of student responses of 90.75% and student activities of 87.15%, both in the category of very practical. The effectiveness of the LKS was shown by the percentage of problem-solving skills of 93.29% and the results of the Wilcoxon test ($p = 0.000 < 0.05$). Thus, this LKS with an AfL approach is declared valid, practical, and effective to train students' problem-solving skills.

Keywords: Assessment for learning; Buffer solutions; Development; Problem-solving skills; Student activity sheet

Introduction

Education has an important role in shaping human resources that are outstanding, flexible, and capable of compete in the global era (Fajartriani, 2024). In the 21st century, education focuses not only on knowledge transfer, but moreover on the growth of critical thinking, creative, collaborative, and problem-solving skills (Trilling & Fadel, 2009). In this context, chemistry learning has an important contribution because it has the capacity to train students to think scientifically and solve complex problems. However, the characteristics of chemistry that are abstract and require an understanding of macroscopic, submicroscopic, and symbolic representations are often challenging for students to comprehend the ideas they are learning (Redhana, 2019).

The application of the Independent Curriculum emphasizes the importance of mastering concept understanding and process skills as part of students' learning outcomes (Badan Standar, 2025). One of the chemical materials that requires mastery of concept understanding and process skills is buffer solutions. This material is considered complex because students must integrate a conceptual understanding of the acid-base equilibrium of conjugates with the ability to perform quantitative calculations. As a result, the concept of buffer solutions is still one of the materials that is prone to causing learning difficulties and misconceptions in students (Kusumaningrum & Kristyasari, 2022). In addition, students still often

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experience misconceptions, such as thinking that all weak acidic or weak alkaline solutions are buffer solutions, and lack of understanding of the function of conjugated acid-base pairs in maintaining the pH of the solution (Afifah et al., 2021).

This problem is reinforced by the outcomes of the preliminary investigation which showed that although 97.1% of students stated that they enjoyed studying chemistry, as many as 62.9% still considered chemistry as a difficult subject. In addition, 60% of students assessed the buffer solution material as being quite difficult to understand. The outcomes of the problem-solving ability test showed that the students' achievement at the stage of compiling a solution plan was still low, which only ranged from 28.38%–32.34%. Other findings showed that 54.5% of students have not set learning targets and 75.8% are not used to choosing problem-solving strategies independently. This condition indicates that students still need guidance that is able to direct the thinking process and solve problems systematically.

Several previous studies have developed AfL-based learning tools on chemical materials. Tiana et al. (2025) developed an AfL-based worksheet to train problem-solving skills on acid-base materials, while Ramadhani (2023) developed an AfL-oriented LKPD on acid-base titration materials, but focused on improving students' critical thinking skills, not on problem-solving skills or buffer solution materials. As far as the author's search is concerned, no research has been found that specifically integrates the AfL approach, formative feedback, self and peer evaluation, and Polya problem-solving stages in a structured manner in a buffer solution material to train students' problem-solving skills. Therefore, this research has novelty in the form of specific integration between the four components into a single SAS device on the buffer solution material, which is designed to guide students gradually in understanding concepts, planning solutions, implementing solutions, and evaluating problem-solving results.

Problem-solving skills are One of the key competencies of the twenty-first century that help students identify problems, analyze relevant information, determine alternative solutions, and make well-informed choices based on their knowledge. These skills also contribute to the advancement of logical thinking and communication skills in the problem-solving process (Ahmad et al., 2022; Rahmadhani et al., 2024).

One approach that can be used is Assessment for Learning (AfL). AfL is a formative assessment approach that utilizes feedback to help students comprehending learning progress and determine steps for enhancement that need to be made (Morris, 2021). Through AfL, teachers can provide constructive feedback so that students are able to reflect on their thinking process, understand the gap between the initial condition and the learning goals, and enhance the standard of instruction in an ongoing manner (Lui, 2022). The pre-study's findings also demonstrated that 90.6% of students felt helped by the feedback given by the teacher and 93.9% of the students followed up on the suggestions given during the process of learning.

The implementation of Assessment for Learning (AfL) can be integrated into the Student Activity Sheet (SAS). SAS is an educational resource created to help students learn actively through a series of structured exercises to enable students to build their understanding independently throughout the process of learning (Handayani et al., 2021). However, the SAS used at SMA Hang Tuah 1 Surabaya still contains summary materials and routine. Questions so that it is not able to facilitate the high-level thinking process or provide formative feedback optimally. Therefore, it is necessary to develop an SAS approach with an AfL approach that can encourage students to engage in active learning, systematically, and reflectively.

The development of SAS with the Assessment for Learning (AfL) approach in this study is designed based on the Polya problem-solving stages, which include understanding the problem, developing a solution plan and implementing it, and evaluating the results (Polya, 1973). Each stage is facilitated through guided questions, formative feedback, as well as self-evaluation exercises and peer evaluation so that students can monitor their learning progress independently. The application of AfL-based learning tools that contain formative feedback in a structured manner has been shown to encourage students to develop their problem-solving skills, as it helps them identify mistakes, reflect on thought processes, and improve problem-solving strategies in an ongoing manner (Tiana & Muchlis, 2025). Based on the problems that have been described, namely the low problem-solving ability of students in the buffer solution material and the lack of optimal SAS used in facilitating high-level thinking processes and providing formative feedback, this research is important to produce SAS with an AfL approach that can help students understand the concept of buffer solutions in depth while practicing systematic problem-solving skills and reflective. This research aims to develop an AfL-based SAS on valid, practical, and effective buffer solution materials to train students' problem-solving skills.

Method

This research uses the Research and Development (R&D) method with a 4D model modified into 3D, namely define, design, and develop. The study was conducted out at SMA Hang Tuah 1 Surabaya with the research subjects of 27 phase f students who were studying buffer solution material. This particular group of subjects was chosen because researchers had previously conducted pre-research to gauge their problem-solving abilities, the results of which showed that those abilities were still low and need improvement. As a result, the 4D model in this study effectively became a 3D model, as the deployment phase was not completed.

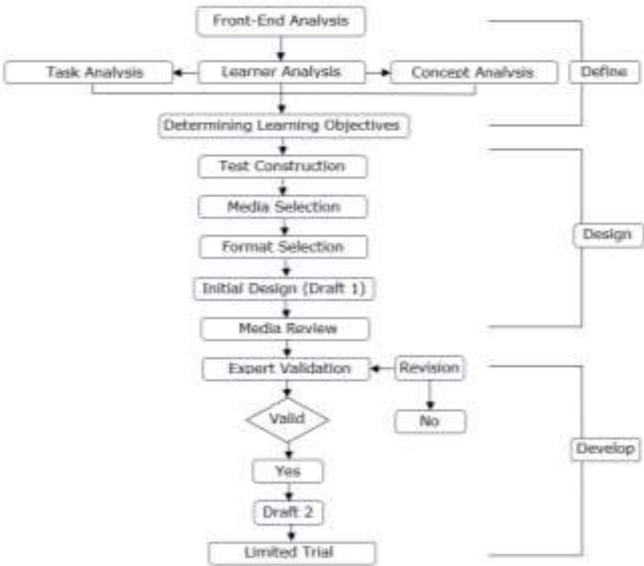

Figure 1. The flow of 3-D model development steps is adapted from (Ibrahim, 2014)

The define stage is carried out to identify learning needs through front-end analysis, student analysis, concept analysis, task analysis, and the formulation of learning objectives. The analysis was carried out to find out the learning problems in the buffer solution material, the characteristics of the students, the concepts learned, and the skills that students must master according to the learning outcomes.

The design stage is carried out by compiling an initial design of the SAS with an AfL approach, including the selection of the SAS format, the preparation of learning activities, and the design of research tools. Activities in the SAS are designed based on the phases of Polya problem-solving, which include comprehending the issue, formulating a plan of action, carrying out the solution, and assessing the outcomes. The SAS is also equipped with guiding questions, self-reflection, and formative feedback to support learners' active engagement in the learning process.

The development stage includes expert validation, product revision, and limited trials. Validation was carried out by 3 validators consisting of 2 chemistry lecturers and 1 chemistry teacher of SMA Hang Tuah 1 Surabaya, to assess aspects of content, language, presentation, and suitability of the AfL approach in the developed SAS. The validation results are the basis for product revisions before the limited trial. The limited trial was carried out on 27 phase F students of SMA Hang Tuah 1 Surabaya using the One Group Pretest-Posttest design. Students are given a pretest before learning using SAS with an AfL approach and a posttest after learning is completed to find out the improvement of students' problem-solving skills.

The research instruments used included validation sheets, student activity observation sheets, student response questionnaires, and problem-solving ability tests. Before use, the problem-solving ability test instrument and student activity observation sheet are first tested for reliability to ensure the consistency of measurement results. The reliability of the problem-solving ability test was calculated using the Alpha Cronbach formula based on the student's answer score on each question item, with the interpretation category referring to Guilford (1956).

Table 1. Reliability Categories

Alpha Value	Category
0.80 – 1.00	Very high
0.60 – 0.79	Height
0.40 – 0.59	Enough
0.20 – 0.39	Low
0.00 – 0.19	Very low

Validity data was analyzed based on the results of validator assessments, while practicality data was obtained from student response questionnaires and activity observation sheets. Effectiveness data were analyzed using the Wilcoxon test and the N-Gain test to determine the difference and magnitude of the improvement in pretest and posttest results of students' problem-solving ability after the implementation of SAS with the Assessment for Learning (AfL) approach.

Table 2. Liker Scale Criteria of Validation

Category	Score
Not Valid	1
Less Valid	2
Quite Valid	3
Valid	4
Very Valid	5

After the SAS approach to Assessment for Learning (AfL) was deemed legitimate in light of the outcomes of the experts' assessment, the product was then tested on Phase F students who had studied the buffer solution material. The trial phase aims to obtain information about the usefulness and efficiency of the SAS developed. Data gathering at this point is carried out through observation of student activities, dissemination of response questionnaires, and the provision of problem-solving skills tests before and after learning.

Product trials using a one-group pretest-posttest design. This design was chosen to identify changes in solving ability. This design was used to assess how student's problem-solving skills changed before and after participating in learning using the SAS with an AfL approach. In the first phase, students are given a pretest to measure their initial problem-solving ability in the buffer solution material. The measured problem-solving ability refers to the phase of Polya this involve comprehending the issue, drafting a plan of action, executing the answer plan, and reviewing the results obtained (Polya, 1973).

After the implementation of the pretest, students took part in learning activities using the SAS with an AfL approach. During the learning process, students receive formative feedback that is integrated into each learning activity. Comments are provided to aid students in comprehending their learning progress, identify gaps between current achievement and learning goals, and encourage reflection on the thought process (Carless & Boud, 2018). In addition, observations of students' activities were carried out to find out their involvement during the learning process using the SAS.

At the end of the learning activity, students are given a posttest to measure their problem-solving skills after receiving treatment. The problem-solving skills measured include the ability to understand problems, develop a solution plan, implement a plan, and evaluate the outcome of the solution. Comparison of pretest and posttest results was used to determine the effectiveness of the SAS developed in improving students' problem-solving skills. In addition to the Wilcoxon test, the improvement of students' problem-solving skills was also analyzed using the N-Gain test to determine the magnitude of the increase in learning (gain score) between pretest and posttest results. The N-Gain value is calculated using the formula (Hake, 1998).

$$\text{Ngain}=\left(\frac{\text{Score Posttest-Score Pretest}}{\text{Maximum score-Score Pretest}}\right)\times 100 \quad (1)$$

The results of the N-Gain calculation are then interpreted based on the categories in Table 7 below. This N-Gain analysis is used to complement the results of the Wilcoxon test, so that the improvement in students' problem-solving ability can be described not only in terms of statistical significance, but also in terms of the magnitude of the improvement in learning that occurs.

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Table 3. N-Gain Interpretation Categories

N-Gain (g) Value	Category
$g \geq 0.7$	Height
$0.3 \leq g < 0.7$	Medium
$g < 0.3$	Low

Student Activity Sheet (SAS) practicality data was acquired through the outcomes of activity observation and student response questionnaires. The data is analyzed using the Guttman scale and presented in the form of percentages to assess the product's degree of usefulness (Riduwan, 2016).

Table 4. Guttman Scale for Observation

Answer	Score
Yes	1
No	0

Before being used to analyze the practicality of SAS, the student activity observation sheet is first tested for reliability to ensure the consistency of the results of observations between observers. Observations were made by 4 independent student observers, then the reliability was analyzed using the Percentage of Agreement (PA) formula (Grinnell, 1988):

$$\text{PA}=\left(\frac{1\text{-(H-L)}}{\text{(H-L)}}\right)\times 100 \quad (2)$$

With H and L, respectively, are the highest and lowest scores of the four observers on each activity indicator. Data on students' activities during learning were gathered using observation sheets and subjected to the following formula for analysis. The categories shown in table 3 are then used to understand the analysis's findings.

$$\text{Score each point}(\%)=\left(\frac{\text{Total score each point}}{\text{Maximum score}}\right)\times 100 \quad (3)$$

Table 5. Practical Score Interpretation

Score Each Point Interpretation	Category
0-20	Not practical
21-40	Less practical
41-60	Enough practical
61-80	Practical
81-100	Very practical

In light of Table 3, student activities are declared to support the feasibility of implementing the SAS with the AfL approach if There is a greater proportion of pertinent activities than irrelevant ones, with a minimum percentage value of ≥ 61% in each indicator.

Table 6. Guttman Scale for Questionnaire

Response	Score	
	Positive Question	Negative Question
Yes	1	0
No	0	1

Based on the categories in Table 4, the SAS is declared practical and receives a favorable answer if the student response questionnaire findings show a percentage of ≥ 61% with the practical category or ≥ 81% with the very practical category (Riduwan, 2016). In addition to assessing the practicality of SAS through activity observation and student response questionnaires, this study also measures the effectiveness of SAS in enhancing students' problem-solving skills. Problem-solving skills were analyzed considering the outcomes of the pretest and posttest given before and after the implementation of SAS using the Assessment for Learning (AfL) approach. The problem-solving score is calculated using a % using the formula below:

$$\text{KPM Value} = \left(\frac{\text{Total scores acquired}}{\text{Maximum score amount}}\right) \times 10 \qquad (4)$$

To ascertain the significance of differences in students' problem-solving abilities both before to and following the execution of the SAS with the AfL approach, The Wilcoxon Signed Rank Test was used to examine the pretest and posttest results. Decision-making is predicated on a significance level of 0.05 and a significance value (p-value). Table 5 displays the Wilcoxon test's decision-making criteria.

Table 7. Interpretation of Wilcoxon Test Results

p (Sig. 2-tailed) Value	Interpretation
$p < 0.05$	The results of the pretest and posttest differ significantly.
$p > 0.05$	The results of the pretest and posttest did not differ significantly.

Result and Discussion

The define stage seeks to determine the underlying needs for the advancement of Assessment for Learning (AfL)-based Student Activity Sheets (SAS) on buffer solution materials. This stage comprises preliminary analysis, student analysis, task analysis, idea analysis, and learning aim development. The preliminary analysis was completed by examining the learning outcomes, learning objectives, and characteristics of the buffer solution substance in the applicable curriculum. The outcomes of the analysis show that students are not only required to understand the concept of buffer solutions, but also to be able to apply these concepts to solve various problems related to daily life. One of the key skills that must be cultivated in 21st century learning is the capacity to apply concepts to solve problems (OECD, 2019). Therefore, learning tools are needed that can make it easier for students must actively participate in their education while practicing problem-solving skills.

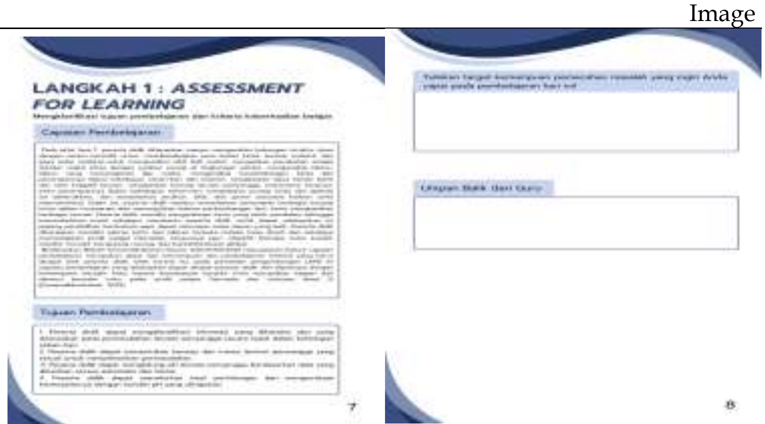
The features of students as users of the developed product were determined through student analysis. Students in the F phase of high school are at the formal operational stage so that they have the ability to think logically and reason about abstract concepts. These abilities are the basis for learning buffer solution material which involves understanding concepts and problem solving. Furthermore, a Concept analysis is used to ascertain the scope of material that will be included in the SAS. According to the analysis's findings, the buffer solution's material comprises the idea of an acid and base buffer solution, its operation, how to calculate its pH, and how it is used in everyday life. These concepts are organized methodically so that students can understand the relationship between concepts and use them in solving the given problems (Novak, 2010).

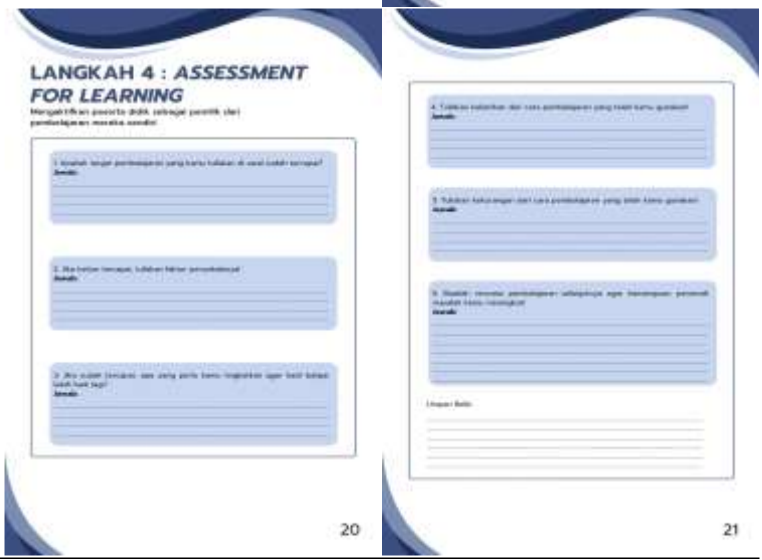
Task analysis is done in order to determine the activities that students need to during learning. Activities at SAS are designed according to the phases of issue-solving abilities, such as problem comprehension, solution planning, problem solving, and reviewing results. In addition, each activity is integrated with the principles of Assessment for Learning through providing feedback and reflection on learning that can support student involvement in monitoring and regulating the process of learning (Panadero et al., 2018). The creation of learning objectives, which serve as the foundation for the development of SAS and research instruments. Learning objectives are formulated based on learning outcomes, characteristics of buffer solution material, and markers of the problem-solving abilities that need to be developed. The results of the definition stage are then used as a reference in the preparation of the initial design of SAS at the design stage.

The design stage resulted in an initial draft (draft I) of the SAS according to Assessment for Learning (AfL) which was developed to train abilities to solve problems with buffer solution materials. The preparation of the SAS was carried out by integrating the four main strategies of the AfL put forward by the (Dylan Wiliam, 2018). That is, clarifying learning objectives and establishing success criteria, creating conversations and tasks that provide learning evidence, giving feedback that promotes learning advancement, and empowering students to take charge of their own education.

In the first step of the AfL, the SAS contains information about learning outcomes and learning objectives that students must achieve. In addition, students are asked to put the goal in writing. problem-solving skills they wish to accomplish during learning. This activity aims to assist students understand the direction of learning while building awareness of the learning goals to be achieved. The presentation of clear learning objectives allows students to know the competencies that must be mastered so that the learning process becomes more directed. This stage is in line with the forethought phase in the self-regulated learning model (Zimmerman, 2002), which is the pre-learning planning stage that involves goal setting as a foundation for students to direct and monitor their own thinking process in the next stages.

Table 8. Pictures and AfL Step Description

AfL Step Description	Image
Student Activity Sheet in step 1 of AfL	
Student Activity Sheet in step 2 of AfL	

AfL Step Description	Image
Student Activity Sheet in step 3 of AfL	
Student Activity Sheet in step 4 of AfL	

Furthermore, in the second step of AfL, students are given contextual phenomena related to buffer solutions in daily life. This phenomenon is used as a basis for identifying and understanding the given problem. This activity is designed according to the indicators of problem-solving ability at the stage of comprehending the issue. Students are directed to identify known information, information asked, and formulate problems based on the phenomena presented. This section also provides a feedback column that allows teachers to respond to students' answers so that they can make improvements in the next stage. Giving feedback at this stage serves as a monitoring process within the framework of self-regulation, which according to Nicol et al. (2006) plays an important role in helping students realize the gap between current understanding and expected understanding, thus encouraging students to make adjustments to thinking strategies independently.

The third step of the AfL is focused on class discussion activities and providing feedback. Each group presented the results of the problem solving that had been obtained, while the other group provided responses, questions, and suggestions on the results of the discussion presented. This activity allows students to act as a learning resource for their peers through the process of providing feedback and evaluation of the work presented (Tai et al., 2018). After the discussion process, the teacher provides feedback to reinforce the concepts that have been learned and correct the mistakes that are still found. Thus, students get information about the advantages and disadvantages of their work so that they can make continuous improvements. Peer evaluation activities at this stage are consistent with the principle of scaffolding in Vygotsky's (1978) sociocultural theory, where social interaction and feedback from peers and teachers act as mediators that help students go beyond their proximal developmental zones in solving complex problems.

In the fourth stage of AfL, students consider what they have learned thus far. Reflection is carried out by evaluating the accomplishment of established learning objectives at the beginning of learning, identifying the factors that cause the target to not be achieved, and determining the improvement initiatives that to be created in order to enhance learning results. This reflection activity aims to help students become capable of keeping an eye on, assessing, and managing their own learning in order to become learning owners (Yan & Brown, 2017). This stage represents the self-reflection phase in the self-regulated learning cycle (Zimmerman, 2002), as well as training the evaluation component in the metacognitive process (Schraw & Moshman, 1995). Thus, the four stages of AfL integrated into the SAS coherently form a complete cycle of self-regulation—planning, monitoring, and evaluation—which theoretically explains why the AfL approach is able to improve students' problem-solving abilities in an ongoing manner, not just in the final achievements.

The development stage produces an Assessment for Learning (AfL) based SAS that is appropriate for usage in learning. At this phase, experts conduct the validation process, which includes limited student trials, product updates based on validator comments, and more. Validation is carried out to ensure that the created product satisfies legitimate requirements and is appropriate for use in education (Nieveen, 2013). Validation involves several validators who have competence in the field of chemistry education. The aspects assessed comprise the suitability of education outcomes and learning objectives, the accuracy of the materials and phenomena used, the suitability of using Assessment for Learning, the linkage of resolving issues skill indicators, and the appropriateness of SAS construction on the content of acid buffer solutions and alkaline buffer solutions. Through this validation process, various inputs and suggestions were obtained that provided the foundation for improving the product.

Based on the validation outcomes, some parts of the SAS were revised to improve the quality of the products developed. Revisions were made to linguistic aspects, presentation of phenomena, clarity of activity instructions, and the suitability between learning activities and indicators of problem-solving ability. The improvement aims to make the SAS easier to understand by students and capable of assisting with the execution of the Assessment for Learning strategy optimally.

Before being used in the trial, the problem-solving ability test instrument and the student activity observation sheet were first tested for reliability. The results showed that the problem-solving ability test obtained an Alpha Cronbach score of 0.681, which was included in the high category (Guilford, 1956), while the observation sheet of student activities observed by 4 observers obtained an average Percentage of Agreement (PA) score of 98.25%, which is included in the very high category (Grinnell, 1988). These results show that the two instruments used in this study are reliable, so the data generated can be trusted to measure the practicality and effectiveness of the SAS developed.

After being revised, the SAS was tested on a limited basis for phase F students on buffer solution materials. The trial was carried out to obtain information about the created product's usefulness and efficacy. Learning implementation observation sheets and student reaction questionnaires were used to collect practicality data, while effectiveness data was obtained through the results of abilities to solve problems skills tests given before and after the use of SAS. The results of the trial show that SAS based on Assessment for Learning can be applied in the gaining knowledge process and has the capacity to facilitate students in carrying out each stage of abilities to solve problems, starting from comprehending issues, organizing solutions, resolving issues, and reviewing the outcomes. These results show that the application of Assessment for Learning provides students with the chance to obtain feedback and reflect throughout the process of learning, in order to facilitate the growth of problem-solving abilities (Panadero et al., 2018).

The development stage produces a final product in the manner of SAS based on Assessment for Learning on buffer solution materials that have undergone a trial, revision, and validation procedure so that they meet the eligibility criteria for use in learning.

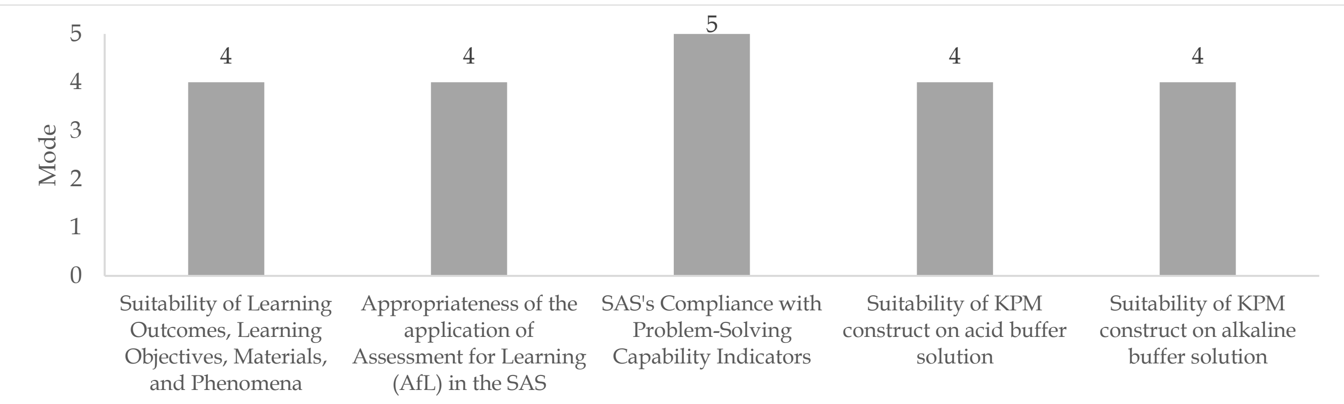


Figure 2. Result of validation student activity

The results of SAS validation based on Assessment for Learning (AfL) are presented in Figure 2. Considering the outcomes of the validator assessment, the aspects of suitability of Learning Outcomes, L earning Objectives, materials, and phenomena obtained mode 4 with a valid category. The element of the suitability of the implementation of AfL in the SAS also obtained mode 4 with a valid category. Meanwhile, the aspect of the SAS's conformity with the problem-solving ability indicator obtained mode 5 with an extremely valid category. Regarding the suitability of the construct, the problem-solving ability of the acid buffer solution and the alkaline buffer solution each obtained mode 4 with a valid category. These findings demonstrate that the SAS generated has satisfied the validity requirements and is appropriate for use in the learning process following modifications made in accordance with the validator's.

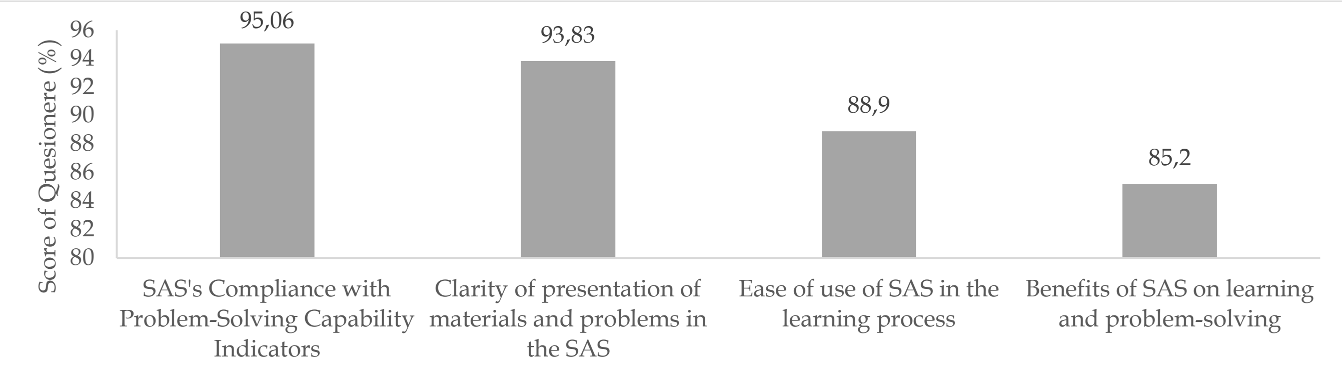


Figure 3. Result of questioner

The findings from the survey of students' answers to SAS based on Assessment for Learning (AfL) are presented in Figure 3. All aspects obtained a very practical category with percentages ranging from 85.20% to 95.06%. The aspect with the highest percentage is the SAS's conformity with the problem-solving ability indicator of 95.06%, which shows that activities in the SAS are able to assist students in completing the phases of problem comprehension, solution design, problem solving, and reexamining the solution's outcomes. In addition, the clarity of the presentation of materials and problems in the SAS obtained a percentage of 93.83%, while the aspect of the ease of use of the SAS acquired a percentage during the learning process of 88.90%. The aspect of SAS's benefits to learning and problem solving obtained a percentage of 85.20%. These outcomes demonstrate that the SAS produced is user-friendly, simple to comprehend, and beneficial in aiding the learning process and students' problem-solving skills.

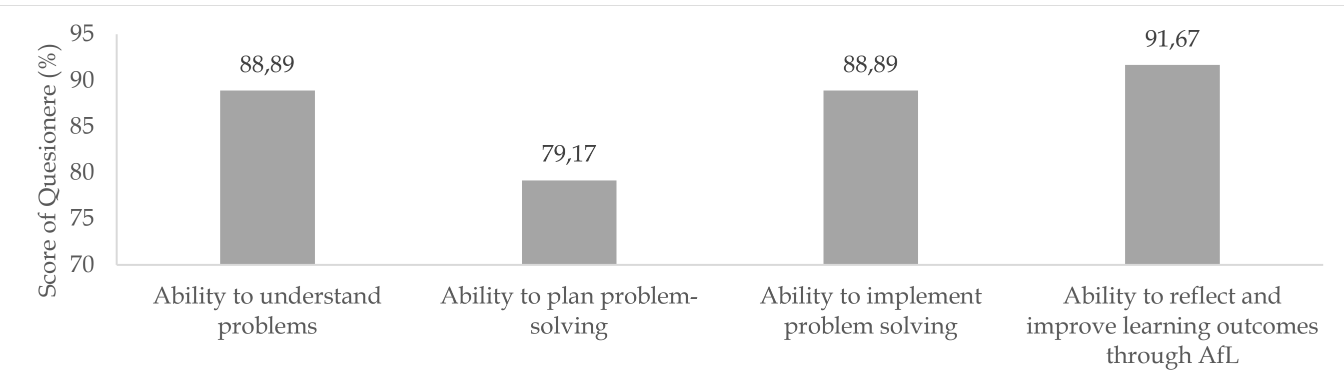


Figure 4. Result of student activity observation

The practicality of the SAS was also reviewed through the findings from observations made during the learning process. Considering Figure 4, the aspect of ability to understand problems obtained a percentage of 88.89% with the category of very practical. The aspect of the ability to plan problem solving achieved 79.17% in the practical area. Furthermore, the aspect of the ability to carry out problem solving obtained a percentage of 88.89% with the very practical category, while the aspect of the ability to reflect and improve learning outcomes through AfL obtained the highest percentage of 91.67% with the very practical category. The results of these observations demonstrate that students are able to follow the activities contained in the SAS well and carry out each stage of problem-solving skills that are integrated with the Assessment for Learning strategy. Thus, the SAS developed meets the criteria for practicality and can be used in learning activities. It should be noted that this observation data was obtained from 4 observers who have been declared to have a very high level of assessment agreement (PA = 98.25%), so that the results of these observations can be relied upon as a basis for assessing the practicality of SAS.

Students' capacity to solve problems after using the created SAS is used to evaluate the efficacy of SAS based on Assessment for Learning (AfL). Effectiveness data was obtained through the outcomes of the problem-solving skills pretest and posttest given before and after learning. The effectiveness analysis was carried out through two stages, namely the calculation of the percentage of achievement of problem-solving ability in each indicator and the Wilcoxon test to ascertain how pupils' problem-solving skills differed before and after using SAS. In addition, an N-Gain analysis was also carried out to determine the magnitude of the increase in students' problem-solving skills between pretest and posttest results.

Four indicators are used in this study to test problem-solving ability: comprehending the problem, planning the solution, solving the problem, and reevaluating the solution's outcomes. Table 5 displays the outcomes of students' problem-solving abilities following the use of AfL-based SAS.

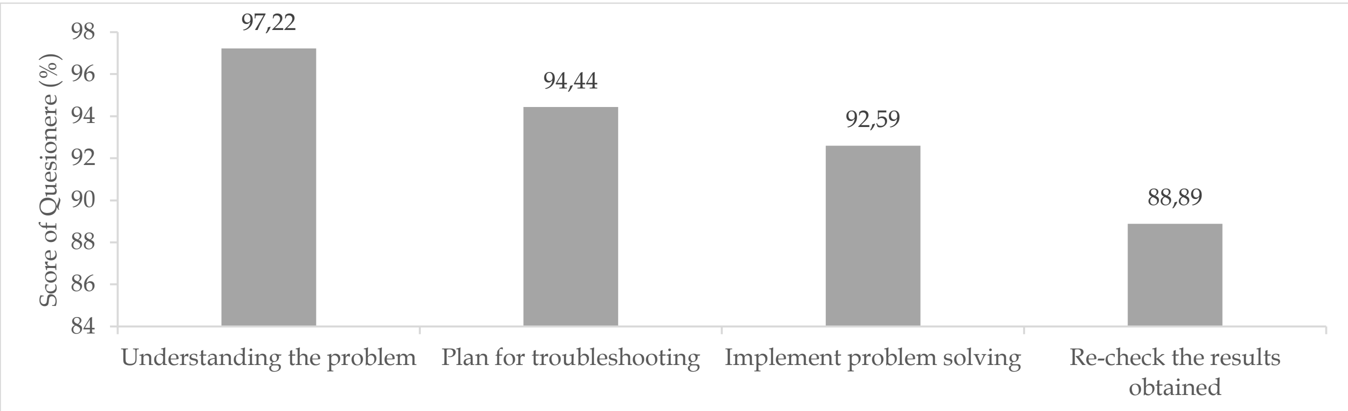


Figure 5. Results of achievement of problem-solving skills

Based on Figure 5, all indicators of problem-solving ability obtained a percentage above 81% so that they are included in the category of very effective. The indicator understanding the problem obtained the highest percentage of 97.22%, while the rechecking indicator obtained the lowest percentage of 88.89%. Despite this, all indicators remain in the very effective category. Overall, students average problem-solving skills were 93.29%, falling into the very effective category. These results show that SAS based on Assessment for Learning is able to facilitate students in carrying out each stage of problem solving according to the Polya indicator. The high achievement in the indicator of understanding the problem compared to the indicator of reviewing the results shows that it is relatively easier for students to build an initial understanding of a problem than to conduct a critical evaluation of the solution that has been made. This is in line with the view of Schraw et al. (1995) who stated that the evaluation component of metacognition is the most complex skill and requires continuous practice, as it requires students to critically reassess their own thought processes, rather than simply carrying out completion procedures.

Table 9. Results of the Wilcoxon Test

		N	Mean Rank	Sum of Ranks
Posttest - Pretest	Negative Ranks	0	.00	.00
	Positive Ranks	27	14.00	378.00
	Ties	0		
	Total	27		

An Asymp. Sig. (2-tailed) value of 0.000 (< 0.05) was found based on the Wilcoxon test findings in Table 9, indicating a significant difference between the pretest and posttest values. The outcomes of positive rankings of 27 students showed that all participants experienced an increase in scores in the posttest compared to the pretest, while there were no negative rankings or ties. The value of Z = -4.553 further corroborates the significant increase after the treatment is given. Thus, According to the findings, students' learning outcomes in the subject matter are improved by the applied learning.

Table 10. Wilcoxon Signed Ranks Test

	Posttest - Pretest
Z	-4.553
Asymp. Sig. (2-tailed)	.000

In addition to the Wilcoxon test, the improvement of students' problem-solving skills was also analyzed using the N-Gain test to determine the magnitude of the increase in learning (gain score) that occurred. The results of the analysis showed an average N-Gain value of 0.68 with a minimum value of 0.29 and a maximum value of 1.00 (SD = 0.166), which is included in the medium category (Hake, 1998). This score shows that the improvement in students' problem-solving skills after the implementation of AfL-based SAS is not only statistically significant, but also practically meaningful, although the improvement has not yet reached the high category. Variations in N-Gain achievement between students (range 0.29–1.00) also indicate that different levels of students' initial mastery also affect the magnitude of the improvement obtained by each individual after the implementation of SAS.

This research produced an Assessment for Learning (AfL)-based Student Activity Sheet (SAS) on buffer solution materials designed help develop students ability to solve problems. The created items' quality is evaluated based on the elements of efficacy, usefulness, and validity. Based on the results of validation by validators, the SAS developed obtained a valid category to be very valid in all aspects assessed. These results show that the material's content, the application of the approach to assessment for learning, and the integration of problem-solving ability indicators in the SAS are in compliance with the learning objectives and features of the buffer solution material. Thus, the SAS developed has fulfilled the eligibility standards for use in the educational process.

The practicality of SAS was reviewed through student response questionnaires and observations during learning, both of which have been declared reliable based on the results of the Alpha Cronbach test (0.681; high category) and Percentage of Agreement (98.25%; very high category). The results of the questionnaire showed that students responded very positively to the use of SAS, while the observation results showed that students were able to follow each stage of the activities contained in SAS well. These findings suggest that SAS is easy to use, easy to understand, and able to support active student engagement throughout the learning process.

The effectiveness of the SAS is demonstrated through the Wilcoxon test and the outcomes of students' problem-solving skills. The findings of the analysis of problem-solving skills showed that all indicators obtained very effective categories. In addition, students' pretest and posttest scores differed significantly, according to the Wilcoxon test results. after using AfL based SAS. These results indicate that the use of SAS is able to help students comprehend issues, devise solutions, address issues, and review the outcomes obtained.

The success of SAS in training problem-solving skills is inseparable from the application of an integrated Assessment for Learning strategy in every learning activity. Through setting learning targets, providing feedback, group discussions, and reflection activities, students have the opportunity to monitor their learning progress and improve their understanding. Theoretically, this success can be explained through the perspective of self-regulated learning, where the four AfL strategies applied—goal setting, feedback, peer discussion/evaluation, and reflection—sequence form the planning, monitoring, and evaluation cycles that are at the core of the metacognitive process (Schraw & Moshman, 1995; Zimmerman, 2002). Feedback provided on an ongoing basis allows students to close the gap (feedback loop) between current learning conditions and the goals they want to achieve (Hattie & Timperley, 2007), while peer discussion and evaluation activities facilitate a process of social scaffolding (Vygotskiĭ et al., 1978) that helps students build problem-solving strategies that were originally beyond the reach of their independent abilities. This combination of metacognitive processes and social scaffolding is the theoretical basis for why the application of AfL has consistently improved students' problem-solving skills, as shown by the significant improvement in all indicators in this study, although the magnitude of the increase (moderate N-Gain) also indicates that there is room for further improvement, for example through the addition of the duration of reflective exercises in the fourth stage of AfL. Therefore, SAS based on Assessment for Learning can be an alternative teaching material that supports chemistry learning, especially in buffer solution materials.

Conclusion

This research produced a Student Activity Sheet (SAS) based on Assessment for Learning (AfL) on buffer solution materials that meet valid, practical, and effective criteria. Based on the validation results, SAS obtained an average score of 4.27 with a valid category.

The practicality results based on student response questionnaires and learning observations obtained an average percentage of 90.75% and 87.15%, respectively, with the category of very practical. The findings regarding students' problem-solving skills, which resulted in an average percentage of 93.29% in the very effective category, showed the effectiveness of SAS. In addition, the results of the Wilcoxon test showed the value of Asymp. Sig. (2-tailed) is 0.000 (< 0.05), which indicates a significant difference between pretest and posttest scores. Thus, SAS based on Assessment for Learning on buffer solution materials is suitable to be used to train students' problem-solving skills. These findings imply that AfL-based SAS can be used as an alternative to chemistry teaching materials to support the development of students' high-level thinking skills, especially in abstract and computation-based materials such as buffer solutions. Structured formative feedback, self-reflection, and peer evaluation integrated in SAS can be a model adapted by teachers to guide students in the process of systematically solving problems on other chemistry topics. However, this study has some limitations. The trial was only conducted in one class consisting of 27 phase F students in one school, so the results of the study could not be generalized to a wider population. In addition, this research is limited only to the define, design, and develop stage of the 4-D model, without reaching the disseminate stage. Therefore, further research is recommended to test SAS on larger and varied samples, as well as proceed to the dissemination stage to assess its application more broadly.

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Author Contributions

Conceptualization, technique, research, data curation, formal analysis, validation, writing—preparing the first draft—and visualization: A.N.C.P.; supervision, project administration, methodology, validation, writing—review and editing: M. All authors have read and agreed to the published version of the manuscript.

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References

Afifah, I. M., Afifah, I. M., & Murniati, D. (2021). Identifikasi Miskonsepsi Terhadap Konsep Larutan Penyangga dengan Menggunakan Instrumen Tes Diagnostic Four-Tier Multiple Choice. *Jurnal Riset Pendidikan Kimia*, *11*(1), 27–34. https://doi.org/10.21009/JRPK.111.05

Ahmad, H., & Furkan, N. (2022). Keterampilan Pemecahan Masalah dan Pengambilan Keputusan Sebagai Keterampilan Pembelajaran dan Inovasi Peserta Didik Abad 21. *PeDaPAUD: Jurnal Pendidikan Dasar Dan PAUD*, *1*(2). Retrieved from https://jurnal.intancendekia.org/index.php/PeDaPAUD/article/view/224

Carless, D., & Boud, D. (2018). The Development of Student Feedback Literacy: Enabling Uptake of Feedback. *Assessment & Evaluation in Higher Education*, *43*(8), 1315–1325. https://doi.org/10.1080/02602938.2018.1463354

Fajartriani, T. H. A. R. D. K. W. (2024). Peran Pendidikan dalam Meningkatkan Kualitas Sumber Daya Manusia. *JEALO: Journal of Economic, Accounting and Local Operations*, *6*(1), 9-17. http://journal.umbogorraya.ac.id/index.php/JEALO/article/view/318

Grinnell, R. M. (1988). *Social work research and evaluation*. F.E. Peacock Publishers.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*(1), 64–74. https://doi.org/10.1119/1.18809

Handayani, E. T., Herdini, & Susilawati. (2021). Pengembangan LKPD Berbasis ICARE (Introduction, Connect, Apply, Reflect, Extend) pada Materi Penentuan Perubahan Entalpi untuk SMA/MA. *Journal of Research and Education Chemistry (JREC)*, *3*(1), 1–13. https://doi.org/10.25299/jrec.2021.vol3(1).6210

Hattie, J., & Timperley, H. (2007). The Power of Feedback. *Review of Educational Research*, *77*(1), 81–112. https://doi.org/10.3102/003465430298487

Ibrahim, M. (2014). *Model Pengembangan Perangkat Pembelajaran menurut Jerold E. Kemp & Thiagarajan*. PSMS PSS Universitas Negeri Surabaya.

Kusumaningrum, I. A., & Kristyasari, M. L. (2022). Misconceptions About Buffer Solutions. *Journal of Educational Chemistry*, *4*(2), 99–108. https://doi.org/10.21580/jec.2022.4.2.12687

Lui, A. M. A. H. L. (2022). The Next Black Box of Formative Assessment: A Model of the Internal Mechanisms of Feedback Processing. *Frontiers in Education*, 7. https://doi.org/10.3389/feduc.2022.751548

Morris, R. P. T. W. L. (2021). Formative Assessment and Feedback for Learning in Higher Education: A Systematic Review. *Review of Education*, *9*(3). https://doi.org/10.1002/rev3.3292

Nicol, D. J., & Macfarlane-Dick, D. (2006). Formative assessment and self-regulated learning: a model and seven principles of good feedback practice. *Studies in Higher Education*, *31*(2), 199–218. https://doi.org/10.1080/03075070600572090

Nieveen, N. (2013). *Educational Design Research*. Netherlands Institute for Curriculum Development (SLO).

Novak, J. D. (2010). *Learning, creating, and using knowledge : concept maps as facilitative tools in schools and corporations*. Routledge.

OECD. (2019). *PISA 2018 Assessment and Analytical Framework*. OECD Publishing. https://doi.org/10.1787/b25efab8-en

Panadero, E., Andrade, H., & Brookhart, S. (2018). Fusing self-regulated learning and formative assessment: a roadmap of where we are, how we got here, and where we are going. *The Australian Educational Researcher*, *45*(1), 13–31. https://doi.org/10.1007/s13384-018-0258-y

Polya, G. (1973). *How to Solve It: A New Aspect of Mathematical Method*. Princeton University Press.

Rahmadhani, K. D., & Fauziah, A. N. M. (2024). Analisis Keterampilan Pemecahan Masalah Siswa melalui Orientasi Masalah Berbasis Wawancara pada Model Problem Based Learning. *Jurnal Basicedu*, *8*(4), 3104–3113. https://doi.org/10.31004/basicedu.v8i4.8516

Ramadhani, N. I. (2023). Pengembangan LKPD Berorientasi Assessment for Learning untuk Meningkatkan Keterampilan Berpikir Kritis Peserta Didik pada Materi Titrasi Asam. *Jurnal Pendidikan Kimia FKIP Universitas Halu Oleo, 8*(3), 171-185. https://doi.org/10.36709/jpkim.v8i3.32

Redhana, I. W. (2019). Mengembangkan Keterampilan Abad Ke-21 dalam Pembelajaran Kimia. *Jurnal Inovasi Pendidikan Kimia*, *13*(1). https://doi.org/10.15294/jipk.v13i1.17824

Riduwan. (2016). *Skala Pengukuran Variabel-Variabel Penelitian*. Alfabeta.

Schraw, G., & Moshman, D. (1995). Metacognitive theories. *Educational Psychology Review*, *7*(4), 351–371. https://doi.org/10.1007/BF02212307

Tai, J., Ajjawi, R., Boud, D., Dawson, P., & Panadero, E. (2018). Developing evaluative judgement: enabling students to make decisions about the quality of work. *Higher Education*, *76*(3), 467–481. https://doi.org/10.1007/s10734-017-0220-3

Tiana, M., & Muchlis, M. (2025). Development of Worksheet Based on Assessment for Learning (AfL) to Improve Problem Solving Skills on Acid-Base Material. *Hydrogen: Jurnal Kependidikan Kimia*, *13*(2), 382–394. https://doi.org/10.33394/hjkk.v13i2.15339

Trilling, B., & Fadel, C. (2009). *21st Century Skills: Learning for Life in Our Times*. Jossey-Bass.

Vygotskiĭ, L. S., Cole, Michael., Stein, Sally, & Sekula, Allan. (1978). *Mind in society : the development of higher psychological processes*. Harvard University Press.

Wiliam, D. (2018). *Embedded Formative Assessment: Practical Techniques for K–12 Classrooms* (2nd edition). Solution Tree Press.

Yan, Z., & Brown, G. T. L. (2017). A cyclical self-assessment process: towards a model of how students engage in self-assessment. *Assessment & Evaluation in Higher Education*, *42*(8), 1247–1262. https://doi.org/10.1080/02602938.2016.1260091

Zimmerman, B. J. (2002). Becoming a Self-Regulated Learner: An Overview. *Theory Into Practice*, *41*(2), 64–70. https://doi.org/10.1207/s15430421tip4102_2