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Development of the Student Worksheets Based on Assessment for Learning (AfL) to Improve Student Learning Outcomes of the Elements Periodic Table

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Abstract: This study aims to develop student worksheets based on assessment for learning to improve student learning outcomes on the elements periodic table, focusing on enhancing students' conceptual understanding. The study uses a 3D development model modified from the 4D model, consisting of three steps: define, design, and develop, applied to class X-7 at a school in Surabaya. Instruments for assessing validity include expert reviews of material and design, with a median score of ≥ 4, indicating content and construct validity. Practicality is measured through student response questionnaires and activity observations, with a positive response mode of ≥ 61%. The worksheet's effectiveness is evaluated through the achievement of learning objectives, with an N-gain value showing 1 student (2.86%) in the medium category and 34 students (97.14%) in the high category. Posttest results show > 75% of students exceeding the passing grade. The Wilcoxon Signed Rank test shows a $P_{value} < 0.05$, indicating a significant difference in student learning outcomes. Based on these findings, the developed worksheet is deemed valid, practical, and effective in improving student learning outcomes.

Keywords: Assessment for learning; Learning outcomes; Periodic table of elements

Introduction

Chemistry is the science that studies matter and its changes (Chang, 2005). Chemistry combines abstract and concrete concepts (Sari & Maharani, 2020). One aspect that illustrates the abstract nature of chemistry is the emphasis on symbolic and macroscopic aspects, such as those found in the material on the periodic table of elements. The periodic table uses many chemical symbols that are related to daily life, such as the symbols for elements (Anipah et al., 2020). For example, understanding chemical symbols such as "Na" for sodium or "Cl" for chlorine is commonly used in chemical reactions or everyday applications (Kurniawati et al., 2023).

The periodic table of elements is one of the topics in the secondary education curriculum, as stated in the Minister of Education and Culture Regulation Number 7 of 2022 concerning Content Standards for Early Childhood Education, Elementary Education, and Secondary Education. In chemistry understanding, the material on the periodic table of elements aims for students to understand atomic structure and its applications in nanotechnology (Kemendikbudristek, 2022). Chemistry is a field of study that offers significant advantages for human life (Ayuningsih & Muna, 2023). The atomic structure consists of protons, electrons, and neutrons, and the arrangement of electrons in the atomic structure is reflected in the outermost electron configuration. Elements with the same outermost electron configuration will have similar properties,

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while elements with different outermost electron configurations will have different properties. Based on this, a grouping of elements emerged, known as the periodic table of elements.

However, many students consider the material on the periodic table of elements to be difficult. A preliminary study conducted at a school in Surabaya showed that 53.1% of students found this material challenging. This aligns with research by Susilawati et al. (2020), which states that students still have difficulty learning the concepts in the periodic table of elements, such as errors in determining electron configurations (19.35%), determining the group and period of an element (64.52%), and the relationship between the properties of elements in the periodic table (70.97%). These difficulties indicate challenges in understanding abstract material, particularly the symbols and concepts related to atomic structure and element grouping.

A clear understanding of the learning objectives for the periodic table of elements material in the curriculum is essential to ensure that educational goals are effectively achieved. These learning objectives not only include knowledge of atomic structure and properties but also the ability to connect these concepts with periodic element properties and their applications in daily life. This aligns with the curriculum's goal of emphasizing conceptual understanding and the application of science in real-world contexts. However, there are significant challenges in achieving these learning objectives. Many students struggle with memorizing element names and understanding abstract concepts related to the periodic table. Research shows that more than 75% of students have difficulty naming elements in the periodic table and understanding the periodic system and the regularity of the chemical properties of these elements (Rahman et al., 2016). Additionally, the concept of trends in the periodic table is often challenging because it involves understanding how the properties of elements change periodically.

These challenges are reflected in student learning outcomes, which have not met the established passing grade. Based on a preliminary study conducted at a school in Surabaya, 62.86% of students scored below the passing grade of 75. Another study by Azizah et al. (2020), at SMA Negeri 2 Mempawah Hilir also showed that only 34.48% of students from class X IPA 1 and 23.07% from class X IPA 2 passed in the periodic table of elements material. This indicates the need for a more effective approach to improve students' understanding of this material. Assessment plays a crucial role in education and the teaching and learning process (Hikmawati et al., 2021). Assessment can influence students' success in achieving competency in science education (Amanda et al., 2023). Assessments should be used to assign grades based on results that align with quality criteria (Azizah et al., 2024).

One solution that can be applied is the use of Assessment for Learning (AfL). AfL plays an important role in improving student learning outcomes because it provides constructive feedback and helps students identify mistakes and areas for improvement (Christianakis, 2010). Evaluation is crucial to determine how effectively the learning has been carried out (Haqiqi et al., 2018). Students can be said to have high-level thinking skills if they can clearly express their ideas (Ramdani et al., 2019). Research by Dini & Muchlis (2022) showed that implementing AfL in learning can improve student outcomes, with the level of completeness reaching 90.91%. In this context, developing student worksheets based on assessment for learning can help students improve their understanding of the periodic table of elements through constructive feedback.

The development of AfL-based student worksheets will provide clear guidance and appropriate steps for students to achieve learning objectives. Previous research by Purnawati et al. (2020) showed that AfL-based worksheets received excellent media assessment results, particularly in terms of interaction and feedback. Therefore, the development of student worksheet based on assessment for learning is expected to be a solution to address the learning outcomes issues in the periodic table of elements material, while also providing a more effective and comprehensive learning experience. Evaluation in AfL-based learning is crucial to assess the extent to which the learning process has been successfully implemented to improve students' critical thinking skills and scientific attitudes (Pursitasari et al., 2023).

The development of AfL-based Student Worksheets has significant potential to improve the quality of chemistry education in Indonesia. AfL focuses on monitoring and improving students' learning processes through constructive feedback, which can help students identify and correct conceptual errors effectively. The implementation of worksheets designed with an AfL approach can facilitate students in achieving better conceptual understanding and improving their learning outcomes (Rohimat, 2021).

Based on the background mentioned, this study aims to develop of student worksheet based on assessment for learning to improve student learning outcomes in the periodic table of elements material. These worksheets are expected to provide accurate feedback, enhance conceptual understanding, and assist students in achieving optimal learning outcomes in accordance with the established standards.

Method

The type of research used is development research by applying the 4-D model, which consists of the define, design, and development stages. In accordance with research needs, the development of the 4-D model is modified into 3-D, or the development stage (Develop) (Thiagarajan, 1976). The research model used in this study is based on the 4-D model, which was modified into a 3-D model, consisting of the define, design, and develop. The "disseminate" stage was removed as it was deemed unnecessary for this study, which focused on creating, testing, and refining the worksheet based on AfL principles (Johan et al., 2023). This modification was made to streamline the research process and keep the focus on the essential stages for the development and evaluation of the worksheet. The 3-D model allows for a concentrated effort on understanding and improving the worksheet's effectiveness in real classroom settings.

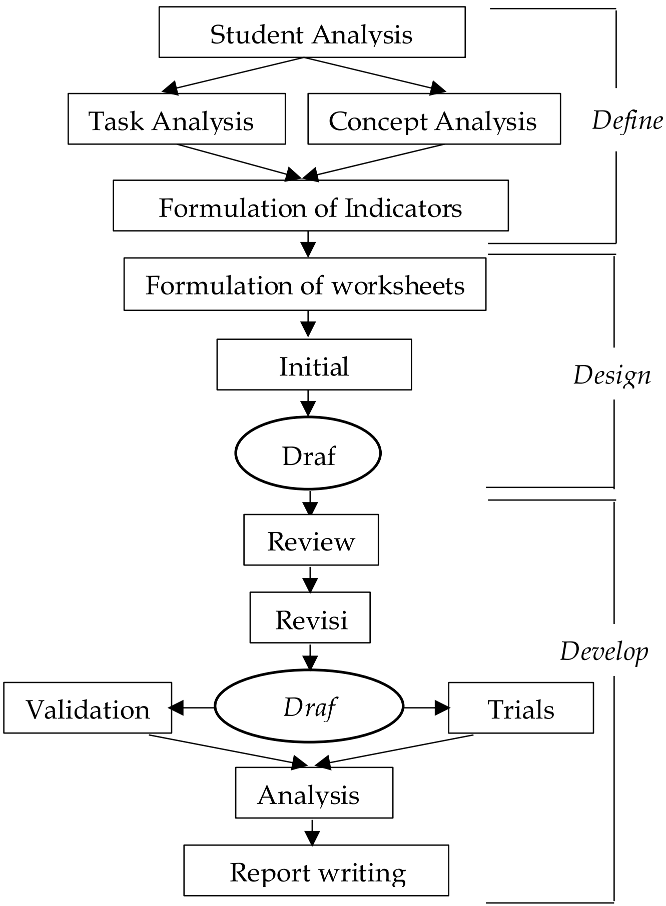

Figure 1. 4D models

The general definition stage includes activities to define the needs of the worksheets to be developed, including analysis of student characteristics including age and learning experience. Then, a task analysis is carried out that is adjusted to the AfL steps, namely the task in the first step regarding writing learning targets, in the second step, namely working on questions in groups, in the third step, namely making presentations, and in the fourth step, conducting self-assessments. Then, in the concept analysis in the form of describing learning outcomes into learning objectives and concept maps, by describing learning outcomes into learning objectives and concept maps is the initial step in learning planning. This helps teachers in designing continuous and systematic learning steps, and ensuring that learning objectives can be achieved effectively (Mutmainnah et al., 2024). Then from this description, the formulation of specific learning objective indicators will be obtained. The target of this study used one trial class, namely class X-7 of SMA Negeri 7 Surabaya.

In design stage, the researcher developed a prototype of the worksheet, which was based on the results of the analysis conducted in the definition stage. The design of the worksheet was guided by the principles of Assessment for Learning (AfL) to ensure it supports formative assessments that enhance student learning. The components of the worksheet include several sections, such as clear learning objectives, tasks related to the periodic table of elements, guiding questions, and spaces for student reflections and feedback. Each task in the worksheet is structured to promote active learning and critical thinking. The worksheet was designed to follow the steps of AfL, which include setting clear learning goals, providing students with constructive feedback, and engaging them in self-assessment (Pratiwi et al., 2022). These steps are integrated into the periodic table of elements material by ensuring that each task addresses key concepts, such as the identification of element groups, understanding the periodic trends, and determining the relationships between elements based on their electronic configurations (Gimeno-Costa et al., 2020). The tasks are designed to help students relate abstract concepts to real-world applications, enhancing their understanding of the periodic table and its relevance. This is in accordance with the research of Fitria et al. (2016) which states that the development of worksheets aims to train students' high-level thinking skills and has been proven validity, practicality, and effectiveness. The worksheet was created for two meetings, with each meeting containing a set of tasks that gradually build on students' understanding of the material. This design allows for a more structured approach to learning and ensures that students receive consistent feedback that guides them through the learning process.

At the development stage, the worksheet is assessed based on three main feasibility parameters: validity, practicality, and effectiveness. The validity of the worksheet is evaluated through content and construct validity. Content validity ensures that the worksheet accurately reflects the key concepts of the periodic table of elements and that the tasks align with the learning objectives, while construct validity assesses whether the worksheet appropriately measures the intended learning outcomes. These validity aspects are evaluated by expert lecturers in the field of chemistry education, as well as a practicing chemistry teacher from a high school, who provide feedback on both the content and structure of the worksheet (Zaenal, 2017).

The practicality of the worksheet is evaluated based on its ease of use and its ability to facilitate student learning effectively. Practicality is also important in choosing a research problem. The practical usefulness of the problem is the main motivation for a researcher to solve a research problem (Pakpahan et al., 2021). The instrument used to assess practicality is a set of observer-based evaluation sheets, where teachers or researchers observe how students interact with the worksheet and rate the degree of engagement, clarity, and usability. If more than 61% of the responses from observers are positive, the worksheet is considered practical (Muna & Rusmini, 2021).

Effectiveness is assessed by analyzing student learning outcomes after the implementation of the worksheet. A pre-test and post-test are used to measure the students' knowledge before and after the worksheet intervention. The N-Gain score is calculated to determine the improvement in learning outcomes, with a target of at least 85% of students achieving scores in the medium or high categories. Effectiveness is also determined by the percentage of students achieving the passing grade of 75 or higher (Hasanah & Muchlis, 2024).

After the expert review and validation, the feedback provided by the expert lecturers and the chemistry teacher is used to revise the worksheet. This process includes revising unclear instructions, improving the alignment of tasks with learning objectives, and refining the accuracy and clarity of the content. Once the revisions are made, the final version of the worksheet is ready for the product trial.

The product trial is conducted with a class of students who will use the revised worksheet in their learning. The trial involves a pre-test to assess the students' initial understanding of the periodic system of elements, followed by the implementation of the worksheet over two sessions. After the learning sessions, a post-test is administered to assess improvements in learning outcomes. Additionally, student responses to the worksheet are collected through a questionnaire, which evaluates the practicality and engagement of the worksheet. The trial data is then analyzed using statistical methods, including the paired t-test or Wilcoxon signed test, depending on the normality of the data, to determine the effectiveness of the worksheet in improving student learning outcomes.

This explanation ensures a clear understanding of the assessment process used in this research, including the instruments and criteria for validity, practicality, and effectiveness, as well as the expert review, validation process, and the product trial analysis.

The worksheet trial conducted in this study used One Group Pre-test-Post-test Design conducted in one class without using a comparison group. The class used as the study will be given a pre-test, treatment, and post-test. The trial was conducted by identifying the initial conditions or before being given of student worksheet based on assessment for learning with a pre-test. Then the treatment of the developed AfL worksheet was carried out. The learning treatment using AfL was given with 2 meetings involving feedback on each task on the AfL steps given. After the treatment was carried out, at the final meeting a post-test would be given to determine the effectiveness of the development of AfL worksheet to improve student learning outcomes.

The data analysis technique used completion of learning objectives, N-Gain, and average difference test. The learning outcomes of students are said to be complete if they achieve a passing grade of ≥ 75. worksheet is then analyzed using N-gain to determine significant differences in learning outcomes, which are said to be effectiveness if the percentage of students is at least ≥ 85% getting a score in the medium and/or high category, namely at a score of $0.7 \geq g \geq 0.3$ (Riduwan, 2016).

Table 1. Data criteria for N-Gain value for learning outcomes

N-gain score	Category
$g \geq 0.7$	High
$0.7 \geq g \geq 0.3$	Medium
$g < 0.3$	Low

Worksheet is also analyzed using the average difference test to find out the comparison of pre-test and post-test scores, by going through a normality test to find out whether the data is normally distributed or not, if the data is normally distributed then it is analyzed using a parametric test (paired t-test), and if it is not normally distributed then it is analyzed using a nonparametric test (Wilcoxon signed test) (Gio & Rosmaini, 2016). Student learning outcomes have significant differences if the P-Value of < 0.05. An effective learning tool (such as an assessment instrument or evaluation tool) will contribute to a high-quality learning process (Utami et al., 2019).

Results and Discussion

Based on the trial of the development of of student worksheet based on assessment for learning, the results obtained were in the form of the following criteria for validity, practicality, and effectiveness.

Validity of Worksheet

Validation of of student worksheet based on assessment for learning was conducted to determine the feasibility of worksheet developed by researchers based on content and construct validity. The validity of this worksheet was analyzed using the median (Widowati & Yonata, 2023). This worksheet is said to be valid if no validator gives a score below 3 and the median is at least 4 or is in the good category.

The validators consisting of two expert lecturers and one chemistry teacher from One of school in Surabaya provided the following results.

Table 2. Worksheet results data on content and construct validity

Validity Criteria	Worksheet	Median
Validity Content	Worksheet 1	5 (Very valid)
	Worksheet 2	5 (Very valid)
Validity Construct	Worksheet 1	5 (Very valid)
	Worksheet 2	5 (Very valid)

Content validity includes aspects of material feasibility, which include the suitability of the material to the curriculum and learning objectives, as well as suitability to the learning approach used. Meanwhile, construct validation includes aspects of presentation feasibility, graphic display, and language use (Zaenal, 2017).

Based on the validity results above, the of student worksheet based on assessment for learning that was developed can be tested on students because it has been declared valid. This is relevant to the research results from Sudarsono & Muchlis (2023), which states that the validity of the worksheet is very valid.

Practicality of Worksheet

The practicality of of student worksheet based on assessment for learning is a measure of the achievement of the objectives of worksheet development, which is measured by a questionnaire of student responses after learning using of student worksheet based on assessment for learning. The practicality of of student worksheet based on assessment for learning is also supported by observation data on student activities during the use of worksheet which is assessed by observers through student activity observation sheets. The practicality of of student worksheet based on assessment for learning is determined based on the most answers (mode).

Data on of student worksheet based on assessment for learning were obtained by distributing response questionnaires after the learning based on assessment for learning trial. The assessment criteria for the response questionnaire were determined through positive or negative statements. The statement was considered positive, if the student answered "Yes" then a score of 1 was obtained and if the answer was "No" then a score of 0 was obtained. worksheet was declared practicality if the mode obtained was one or received a positive response from students. The responses given by students based on of student worksheet based on assessment for learning trial are presented in Table 3 below.

Table 3. Student response questionnaire results data

Statement Number	Positive Response
1	100
2	100
3	100
4	100
5	97.14
6	100
7	94.29
8	100
9	91.43
10	85.71
11	97.14
12	85.71
13	100
14	94.29

Based on Table 3 regarding student response data, it is known that each statement in the student response questionnaire received a percentage of at least 85.71%, and the mode obtained was 100%. This proves that student responses to of student worksheet based on assessment for learning are included in the very good category, because they have a positive response mode from students (Riduwan, 2016). This finding is in line with research conducted by Dini & Muchlis, (2022) which states that the application of AfL in learning is practicaly to improving student learning outcomes in the material on the periodic system of elements.

The practicality data is supported by the student activity observation sheet filled out by 6 observers who observed 6 different groups. The assessment criteria for the student activity observation sheet are determined through positive or negative statements. The statement is considered positive, if the student answers "Yes" then a score of 1 is obtained and if the answer is "No" then a score of 0 is obtained. Worksheet is declared practicality if the mode obtained is one or gets a positive response from the observer. The results of the student activity observation are presented in Table 4.

Based on Table 4 regarding student activity observation data, all teacher activities in implementing of student worksheet based on assessment for learning were carried out well, as evidenced by obtaining positive responses to each statement with a percentage obtained of 100%. This proves that the observation of student activities on the of student worksheet based on assessment for learning is included in the very good category, because it has a positive response mode from students (Riduwan, 2016).

Table 4. Data from student activity observation results

Activities	Positive Response
1	100
2	100
3	100
4	100
5	100
6	100
7	100
8	100
9	100

Student worksheet based on assessment for learning is said to be practicality if the percentage of practicality obtained from the response questionnaire supported by the activity observation sheet is ≥ 61%. Based on the results of the student response questionnaire, the percentage result is at least 85.71%. While the results of the student activity observation, the percentage result is at least 83.33%. Thus, student worksheet based on assessment for learning is categorized as practicality to improve student learning outcomes in the material of the periodic system of elements.

Effectiveness of Worksheet

Data on students' cognitive learning outcomes were obtained by giving pretest and posttest questions consisting of 20 questions to students of class X-7 of One of school in Surabaya. Analysis of students' learning outcomes will be carried out using completion of learning objectives, N-Gain, and average difference test.

The completion of students' learning objectives on the elements periodic table is obtained from the pretest and posttest scores that have been completed by students. Learning objectives can be said to be complete if at least 75% of students achieve individual completion. The results of the pretest and posttest are presented in Table 5.

Each pretest and posttest that students have done will receive feedback from the teacher. Student learning outcomes depend on the quality and detail of the feedback (Sudirman et al., 2023). Based on Table 5, the pretest results show that no students have achieved the completion of learning objectives, namely obtaining a score above the passing grade (≥ 75). The posttest results show that all students, namely 35 students (100%) have achieved the completion of learning objectives. A total of 35 students were declared complete, indicating that > 75% of students achieved individual completion. These results indicate that the learning objectives are said to be complete. Thus, the application of learning based on assessment for learning is effectiveness in improving student learning outcomes in the material on the periodic system of elements.

Table 5. Student pretest and posttest results

Student	Completion of Pretest	Completion of Posttest
1	Not Complete	Complete
2	Not Complete	Complete
3	Not Complete	Complete
4	Not Complete	Complete
5	Not Complete	Complete
6	Not Complete	Complete
7	Not Complete	Complete
8	Not Complete	Complete
9	Not Complete	Complete
10	Not Complete	Complete
11	Not Complete	Complete
12	Not Complete	Complete
13	Not Complete	Complete
14	Not Complete	Complete
15	Not Complete	Complete
16	Not Complete	Complete
17	Not Complete	Complete
18	Not Complete	Complete
19	Not Complete	Complete
20	Not Complete	Complete
21	Not Complete	Complete
22	Not Complete	Complete
23	Not Complete	Complete
24	Not Complete	Complete
25	Not Complete	Complete
26	Not Complete	Complete
27	Not Complete	Complete
28	Not Complete	Complete
29	Not Complete	Complete
30	Not Complete	Complete
31	Not Complete	Complete
32	Not Complete	Complete
33	Not Complete	Complete
34	Not Complete	Complete

Student	Completion of Pretest	Completion of Posttest
35	Not Complete	Complete
	Complete : 0 (0%)	Complete : 35 (100%)
	Not Complete : 35 (100%)	Not Complete : 0 (0%)

To find out the increase in student learning outcomes, it is measured using the N-gain value, which is obtained by comparing the results of the student's pretest and posttest. The questions given in the pretest and posttest are the same. Students are said to have experienced an increase in learning outcomes if the N-gain shows results in the medium or high category (Hake, 1998). The data on the results of the students' N-Gain scores are presented in Table 6 below.

Table 6. N-Gain test results of student learning outcomes

Student	N-Gain	Category
1	0.79	High
2	0.85	High
3	0.75	High
4	0.83	High
5	0.85	High
6	0.87	High
7	0.64	Medium
8	0.93	High
9	0.81	High
10	0.87	High
11	0.81	High
12	0.73	High
13	0.89	High
14	0.87	High
15	0.75	High
16	0.85	High
17	0.80	High
18	0.92	High
19	0.73	High
20	0.73	High
21	0.81	High
22	0.87	High
23	0.88	High
24	0.76	High
25	0.80	High
26	0.86	High
27	0.76	High
28	0.73	High
29	0.92	High
30	0.82	High
31	0.86	High
32	0.86	High
33	0.87	High
34	0.82	High
35	0.80	High

Based on Table 6, the learning outcomes of students have increased, as observed from the improvement in scores between the pretest and posttest. The data shows that the increase in learning outcomes is reflected in 1 student (2.86%) in the medium category and 34 students (97.14%) in the high category. These results indicate that the application of learning based on assessment for learning has been effective in improving student learning outcomes.

To further support this conclusion, the N-Gain was calculated for each student, which measures the effectiveness of the learning intervention by comparing the difference between pretest and posttest scores while considering the maximum possible improvement. The N-Gain values for the class show that 97.14% of students have an N-Gain greater than 0.7, which is categorized as high, while 2.86% of students fall into the medium category, with an N-Gain between 0.3 and 0.7. According to Riduwan (2016), an N-Gain of $0.7 > g > 0.3$ corresponds to a medium or high category, indicating a significant improvement in learning outcomes. This finding aligns with research by Safithri & Muchlis (2022) and Maulida & Nur (2024), which also concluded that the implementation of AfL significantly enhances student learning outcomes, particularly in the context of learning the periodic system of elements. Therefore, the N-Gain data strengthens the results of the Wilcoxon Signed Rank Test, which showed a significant improvement in posttest scores compared to pretest scores. The combination of these analyses demonstrates that AfL is an effective approach in improving student learning outcomes.

To find out the significant average differences of students, a mean difference test was conducted. The mean difference test of the test results must be known whether they are normally distributed or not through a normality test using Minitab 18. The pre-test and post-test score data must be analyzed whether they include data with a normally distributed population using a normality test as a requirement for the parametric test. The normality test uses the help of Minitab 18 software. The data were analyzed using the following hypotheses:

H_0 = data is normally distributed.

H_1 = data is not normally distributed.

Table 7. Results of pre-test and post-test data normality test

Mark	P_{Value}
Pretest	< 0.01
Posttest	< 0.01

Decision making is based on the P_{Value} value with the criteria that if the P_{Value} value is > 0.05 then H_0 is accepted and H_1 is rejected, which means the data is normally distributed, whereas if the $P_{Value} < 0.05$ then H_0 is rejected and H_1 is accepted, which means the data is not normally distributed. The normality test is presented in Table 7. Based on the normality test in Table 7, it shows that the overall pretest and posttest values get a P_{Value} of < 0.05, so it can be concluded that the data is not normally distributed. This deviation from normality can be attributed to several factors, including extreme data, sorted data, data that follows a distribution other than the normal distribution, and many other causes (Sari et al., 2017). Other factors, such as varying levels of student prior knowledge, involvement, or external influences during the testing period, can also contribute to the non-normal distribution of data.

Therefore, considering that the normality assumption is not met, a non-parametric statistical test is used, specifically the Wilcoxon Signed Rank Test (Sugiyono, 2007). This test is suitable for analyzing data that does not meet the normality assumption, allowing us to compare pre-test and post-test scores of student learning outcomes without relying on data normality. The hypothesis that can be given is as follows.

H_0 = The posttest value is smaller or equal to the pretest of student's learning outcomes after the implementation of learning based on assessment for learning.

H_1 = The posttest value is higher than the pretest of student's learning outcomes after the implementation of learning based on assessment for learning.

Decision making is based on the P_{Value} value with the criteria that if the P_{Value} value is > 0.05 then H_0 is accepted and H_1 is rejected, whereas if the $P_{Value} < 0.05$ then H_0 is rejected and H_1 is accepted. Test Wilcoxon Signed Rank presented in Table 8 below.

Table 8. Results of Wilcoxon Signed Rank Test

Mark	Result
Test	35
Statistics	630.00
P_{Value}	.00

Based on Table 8, the results of the Wilcoxon Signed Rank test show that the P_{Value} is < 0.05. This indicates that the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_1) is accepted. Specifically, the rejection of H_0 implies that the posttest score is higher than the pretest score of students' learning outcomes after the implementation of learning based on assessment for learning.

The Wilcoxon Signed Rank test is a nonparametric statistical test used to compare two related samples. In this case, this test compares the pretest and posttest scores, and by obtaining a P_{Value} of < 0.05, we conclude that the difference between the two sets of scores is statistically significant. This indicates that the implementation of AfL in the learning process has had a measurable impact on student performance, thereby improving their learning outcomes.

The results of this study support the research hypothesis that the posttest score will show a significant difference with the pretest score after the implementation of learning based on assessment for learning This finding is in line with previous research conducted by Pratama & Muchlis (2023) and Hasanah & Muchlis, (2024), which concluded that the application of AfL was effective in improving student learning outcomes, especially in the context of learning the periodic table of elements.

Conclusion

Based on the results of the research and discussion on the development of student worksheet based on assessment for learning on the material of the periodic system of elements in class X-7 at one of the schools in Surabaya, the following conclusions can be drawn: The student worksheet based on assessment for learning on the material of the periodic system of elements that was developed was found to be valid in terms of content and construct criteria, as it received a median score of ≥ 4 in each aspect; The worksheet was also considered practical, based on the positive responses received from the response questionnaire and activity observation sheets, with more than 61% of responses being positive; The worksheet proved to be effective, as evidenced by student learning outcomes showing that 100% of students achieved scores above the passing grade (≥ 75), which means all students were declared complete. Additionally, over 75% of students achieved individual completeness. The learning outcomes were further supported by the N-gain value, which showed that 1 student (2.86%) was in the medium category, and 34 students (97.14%) were in the high category. The Wilcoxon Signed Rank test results indicated a $P_{Value} <$ 0.05, which demonstrates a significant difference between the average pre-test and post-test scores of students' learning outcomes after the implementation of learning based on assessment for learning.

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Data collection permission, media development and learning instruments, data collection, G.F.S.; research data analysis, G.F.S. and M.; article preparation, M. All authors have read and agreed to the final version of the published manuscript.

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