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Development of Pjbl-SSI Based E-LKM on Chemical Thermodynamics Materials

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A B S T R A C T

In the 21st century, learning in higher education must be meaningful and interactive. In physical chemistry learning, students often experience difficulties because it is theoretical. Based on this, interactive teaching materials are needed to support learning and are in accordance with the demands of the times. This study aims to develop a chemical thermodynamics E-LKM based on PjBL-SSI (Project Based Learning-Socio Scientific Issue). This research was conducted at the Chemistry Education Study Program, University of Riau in the physical chemistry course. The population in this study were 5th semester chemistry education students. The sample in this study was chemistry education students. The type of research used in this study is development research with the ADDIE model. The results of the study indicate that the developed E-LKM is valid according to the material and media validator. The developed PjBL-SSI E-LKM is practical according to the physical chemistry lecturer with a very good category and the developed E-LKM is interesting according to students with a very good category.

1. Introduction

21st century education emphasizes four skills that must be possessed by each individual, these skills are known as 4C skills, namely Communication, Critical Thinking, Creativity, Collaboration. Educators must be able to develop lesson plans that contain activities that challenge students to 4C skills. Learning in higher education emphasizes the importance of project-based learning. This is in accordance with the Decree of the Minister of Education and Culture Number, requiring that learning must use case-method and project-based learning with an assessment weight of 50%. The Decree of the Minister of Education and Culture emphasizes the importance of project-based learning models in responding to the demands and developments of the times based on the noble values of the nation.

One of the project-based learning models that can be used in higher education is project-based learning (PjBL). PjBL is one of the learning models that is in accordance with the demands of the 21st century and which is applied in universities today. This is in line with Dewi's research (2024) which states that project-based learning, in particular, has been identified as a model that is very suitable for implementation at the current college level. The syntax of the PjBL model is 1) Determine relevant topics and conduct in-depth investigations, 2) Designing project planning, 3) Developing a project schedule, 4) Testing results, 5) Testing results, 6) Reflection on project activities and results. Based on this syntax, PjBL is very suitable to be applied to learning in universities that have adult learning methods. The concept of adult learning is known as andragogy learning. Andragogy, as used in adult education, refers to a collection of ideas or principles that support people in acquiring the information, attitudes and skills needed to improve their quality of life (Saputra 2024).

Project-based learning is suitable for college courses including Physical Chemistry. One of the materials in Physical Chemistry is Chemical Thermodynamics. In thermodynamics, the relationship between heat, work, temperature and energy is studied. Thermodynamics continues to evolve and presents new challenges for scientists in the development to improve energy efficiency. Based on Sinensis' research (2018), in order to make learning thermodynamics easier to understand and attract students' attention, it is necessary to integrate IT and collaborative learning.

Learning with the PjBL model can be integrated with the Socio Scientific Issues (SSI) approach. SSI-based learning according to Yuliastini (2016) can be done with four stages, namely Scientiif background, evaluation of information, Impact of Local, National and Global Dimension, decision making. One of the topics discussed in Socio Scientific Issue is environmental issues. Nowadays, SSI is one of the approaches that must be integrated in chemistry learning because it can encourage students to be sensitive and see how science views social issues that occur daily. The SSI approach is a contextual-based approach. The resolution of the issues raised requires continuous information search stages (Rery 2023). Based on Hanifa's research (2023) learning using the SSI approach can improve science literacy and environmental awareness of chemistry education students.

The essence of a research is the existence of a problem that must immediately find a way out. Not only limited to literature searches, researchers have conducted interviews and observations at the Chemistry Education Study Program at Riau University, UIN Suska Riau and Muhammadiyah Riau University. Interviews were conducted with lecturers of the Physics course, namely Mrs. ME, Mr. AY and Mrs. SH. Based on the results of the interview, it was found that in the learning process students have difficulty in Chemical Thermodynamics because they still apply chemistry in middle school and are memorized. Physical chemistry material requires high understanding and in this thermodynamic material requires mathematical understanding. Due to the learning of physical chemistry many are theoretical, so learning that supports collaborative skills has not been widely applied. Researchers also conducted pre-research with interviews with students.

From the results of the interview, it is known that students prefer the discussion method in learning and the use of IT in the learning process. Students consider physical chemistry courses to be one of the most difficult because the theoretical concepts are not close to everyday life.

LKM is one of the instruments needed in classroom learning. The role of the LKM is to help students understand the material and help lecturers deliver material according to the learning objectives that have been formulated (Indayati, 2020). The E-LKM supports students in carrying out problem-solving activities so that the results of student work on the LKM can help students to actively participate in the lecture process (Ramadhan 2023). E-LKM are made by design according to the material and student needs, besides that LKM are tools used by lecturers in assisting the acquisition of knowledge during the learning process (Rahmatya 2019). The thermodynamic E-LKM developed in this study uses the liveworksheets website. Liveworksheets is a website-based application provided free of charge by the Google search engine. This application allows teachers to turn conventional printable worksheets (document, pdf, jpg, or PNG) into interactive online exercises while automatically correcting student work. Liveworksheets. has advantages including that it can be used on devices for free without the need to download the application (Aisyah 2023).

Previous research related to this research has been conducted by Maolida (2024) with the title "SSI-Integrated PjBL Model in Biodiversity Topics" based on the findings in the study showed that PjBL-SSI can improve Digital Literacy. Furthermore, the research findings of Kurniasari (2024), the PjBL-SSI Model is effective in improving student learning outcomes. Fitriyani (2025) stated that PjBL-SSI can also improve critical thinking skills. Islawati (2024), based on her findings PjBL can improve student collaboration skills. This is in line with the research of Mora (2023) and Syafii (2023). Based on the problems that have been explained, the aim of this research is to produce E-LKM PjBL-SSI on thermodynamics material that is valid according to the material validator and media validator and is practical according to the lecturer and can be used in physical chemistry learning.

2. Methodology

This research was conducted at the Chemistry Education Study Program at Riau University in the physical chemistry course. This research was conducted in the 2024/2025 academic year in the odd semester, the research time was held in November - December 2024. The population in this study were 3rd semester chemical education students. The sample in this study were 36 students. The sampling technique used in this study was purposive sampling. This PjBL-SSI-based E-LKM on Chemical Thermodynamics material was developed using the ADDIE development model which consists of 5 stages, namely analysis, design, development, implementation and evaluation. The ADDIE development model was developed by Dick and Carry (1996) to design learning systems. The researcher modified the development model according to the needs. tthe development flow with the addie model can be seen in figure 1.

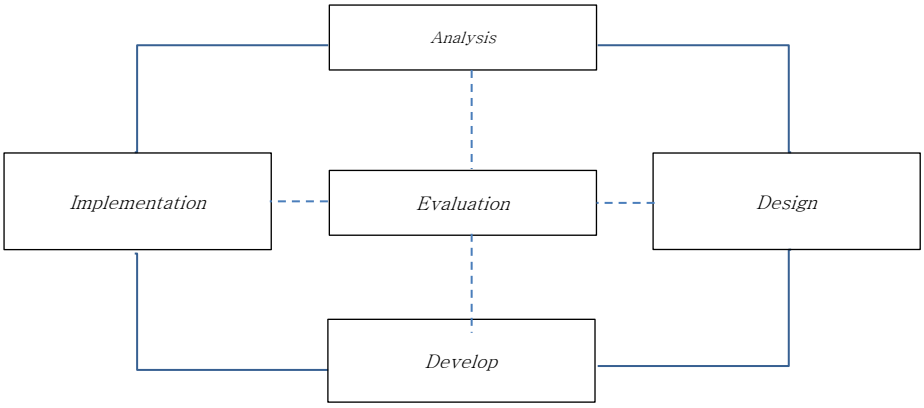


Figure 1. ADDIE Development Model

Data from the validation sheet research results were obtained from the validation results of 6 expert validators, consisting of 3 material experts and 3 media experts who were asked to fill out the validation sheet as an assessment of the feasibility of the developed PjBL-SSI-based E-LKM. The data obtained from the validation sheet assessment is in the form of a scale. The type of scale used is a Likert scale with a score of 1-4. This scale provides flexibility to validators in assessing the validity of the E-LKM teaching materials that have been developed. The following Likert scale assessment categories by validators are shown in Table 1.

Table 1. Likert Scale Rating Categories

Criteria	Score
Very Good	4
Good	3
Fairly Good	2
Not good	1

From the Likert scale assessment category table Table 1, the average percentage of each component will be calculated using the following formula:

$$P = \frac{\sum x}{\sum xi} \text{ x } 100\%$$

Description:
P : Percentage score (rounded)
$\sum$ x : The number of respondents' answer values in one item
$\sum$ xi : Number of ideal scores in one item

Giving meaning and making decisions about the quality of ELKM products will use the conversion of achievement levels with a scale of 5 as in Table 2.

Table 2. Criteria for validity of validator assessment sheet data

Percentage	Criteria
81-100	Very feasible/very valid/no need for revision
61-80	Feasible/valid/no need for revision
41-60	Less feasible/less valid/need for revision
21-40	Not feasible/not valid/need for revision
<20	Not feasible/very invalid/need for revision

Practicality test assessment data is obtained based on the assessment of practicality by physical chemistry lecturers on the use of teaching materials. While the data on the results of the attractiveness test assessment is obtained based on the assessment of attractiveness by students to the use of E-LKM PjBL-SSI teaching materials. The average score results from the practicality assessment sheet by lecturers and the attractiveness assessment sheet by students that have been obtained are then converted into qualitative data to determine the practicality criteria for the use of E-LKM which can be seen in Table 3.

Table 3. Criteria for Assessment of Practicality and Attractiveness Sheets

Percentage	Criteria
81 – 100	Excellent
61 – 80	Good
41 – 60	Fair
21 – 40	Deficient
< 20	Very Deficient

(Arikunto, 2013).

3. Results and Discussion

This research is a development of PjBL-SSI-based chemical thermodynamics E-LKM in physical chemistry I course. Thermodynamic material provides a strong and universal framework for understanding energy transformations and the behavior of chemical systems. The uniqueness of this material lies in its ability to connect macroscopic properties with fundamental laws, as well as its wide application in various fields of science and technology. The data obtained in this study are in accordance with the research method of developing E-LKM PjBL-SSI through research and development (R&D) design by adapting the ADDIE development model, which is a development model consisting of five stages including analysis, design, development, implementation and evaluation.

Analysis Stage

Initial analysis was conducted by interviewing two lecturers of Physical Chemistry I in the Chemistry Education Study Program at Riau University and Muhammadiyah Riau University Based on the interviews, it is known that in the learning process of Physical Chemistry I, Problem Based Learning, Case Study-based learning models have been applied, with discussion and assignment methods. It is also known from the learning model and teaching materials used, there are several obstacles in learning Physical Chemistry such as students having difficulty understanding mathematical concepts, as we know that mathematical concepts are tools and as one of the requirements for studying physical chemistry.

Student analysis was carried out by providing a questionnaire containing questions related to physical chemistry learning, learning methods, and difficulties experienced by students in learning physical chemistry. The results obtained are that students prefer discussion methods and group learning methods. learning

resources that students often use are from books and other sources from learning websites. Based on the questionnaire, it is also known that students prefer electronic teaching materials. Some students have heard the term SSI but do not really know clearly about social science issues.

Curriculum analysis aims to review the curriculum implemented by the University and Study Program so that the preparation and development of E-LKM can be in accordance with the curriculum used. Based on the results of curriculum analysis, thermodynamic material has two sub-course outcomes and course achievement indicators. (1) The accuracy of analyzing the spontaneity of chemical systems (2) The accuracy of predicting the spontaneity of chemical systems (3) The accuracy of explaining the second law of thermodynamics in the Carnot heat engine (4)The accuracy of applying the second law of thermodynamics to the Carnot heat engine.

The material analysis contained in the E-LKM is made based on chemical thermodynamics materials that are in accordance with CPMK and Sub-CPMK and are compiled using several sources/literature. The materials contained in the E-LKM are the first law of thermodynamics, entropy and spontaneity of reactions, the carnot cycle, and the application of the second law of thermodynamics to the carnot heat engine.

Design phase

The design of the E-LKM display is done with the help of Microsoft Publisher software and Canva editing application. The initial design of the E-LKM will produce a storyboard. The storyboard is made to organize the E-LKM framework that will be developed according to the E-LKM needs and ensure that each E-LKM display can convey messages efficiently and effectively.

The preparation of material or content of the PjBL-based SSI E-LKM prototype is compiled referring to the learning indicators and materials that have been described at the material analysis stage. The content of the E-LKM is taken from sources in the form of Atkins Physical Chemistry books, Dogra Physical Chemistry, scientific journal articles, and the internet relevant to Chemical Thermodynamics material. Prastowo (2015) says if the LKM can be equipped with a summary of the material, tasks and instructions for implementing learning activities. The learning activities compiled in the E-LKM refer to the syntax of the SSI model, namely Scientific Background, Evaluation of Information, impact of local, national and global and the decision making stage which is integrated with the PjBL stages that take place from meetings 1-4. The PjBL-SSI stages implemented are presented in table 4.

Table 4. Stages of PjBL-SSI

No.	Stages of PjBL-SSI	Activity
1.	Scientific Background	At this stage, issues will be presented from the perspective of social and scientific knowledge that exists in the community. This stage will direct learners' perceptions that the issues presented can be resolved scientifically.

2.	Evaluation of Information	This stage will direct learners to explore information from various sources to increase learners' knowledge about the issues presented.
3.	Impact of Local, Nasional and Global Dimension	At this stage learners are asked to examine the impact of the issues discussed on a local, national and global scale. Then learners are asked to find solutions or solutions to the issue.
4.	Decision Making	At this stage, students are asked to draw conclusions and convey the benefits related to the social science issues discussed.
5.	Determine a relevant topic and conduct an in-depth investigation	Students set the project theme and are active in conducting investigations according to the topic
6.	Design a project plan	students make project designs in groups
7.	Develop a project schedule	Students have been orderly working on the E-LKM making timelines and deadlines for completing projects
8.	Test results	At this stage the activities carried out evaluate project progress and feedback and reinforcement of material. Students are very enthusiastic in the project. Then the lecturer provides reinforcement of learning materials.
9.	Evaluate the experience	Students and lecturers evaluate the process and results of the project.
10.	Reflect on project activities and results	Students in all groups reflect on the activities and project results that have been made.

Development Phase

This development phase has 2 stages, namely the prototyping process and prototype validation. In the prototyping process, Microsoft Publisher and Canva software were used to create each page in the prototype. The prototype that has been developed in Pdf format is then uploaded to the Liveworksheets website. On the Liveworksheets website, the prototyping process is continued by designing the interactions in it to be interactive, namely by adding images, videos, material links, shapes for E-LKM answers and navigation buttons.

As for uploading answers to the E-LKM, the google form link that has been embedded in the answer box is used. After completion, the liveworksheets are published to students in a link format that can be accessed online. The next stage is an assessment in the form of validation, small-scale testing and large-scale testing. Material validation was carried out by 3 material validator lecturers using a validation sheet in the form of a 1-4 Likert scale. Material expert validation assessment is based on aspects of content feasibility, presentation feasibility, language feasibility, graphics, PjBL-SSI assessment, computational thinking aspects, and collaborative skills.

In the first validation, the average percentage of the 7 aspects was 82% with a decent or valid category. In the first validation, in addition to the product validity score, suggestions and input from each material validator were also obtained to improve the E-LKM. Based on suggestions and input from validators, researchers will make improvements. In this case, there are several things that need to be improved,

namely regarding the concept of thermodynamic material, so that in this aspect it is necessary to improve the concept of material for reducing the formula for changes in environmental entropy because there are still incorrect signs.The results of material validation can be seen in Figure 2.

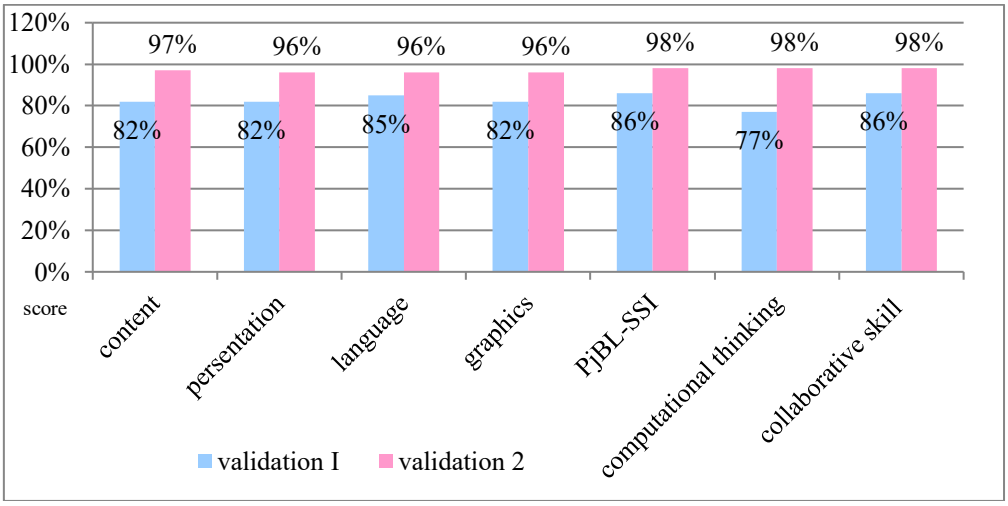
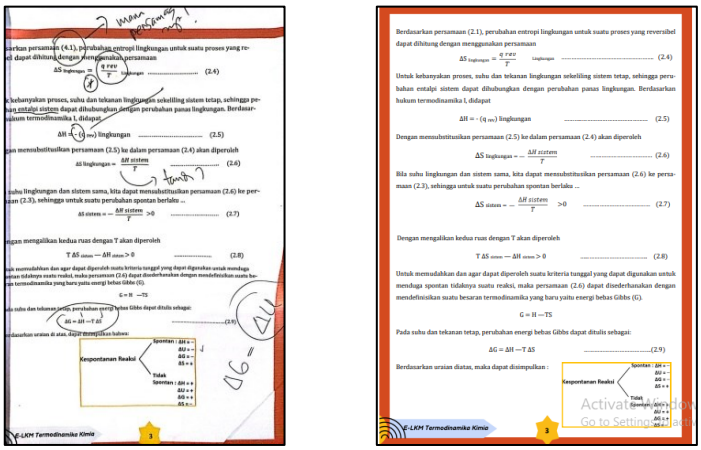


Figure 2. Results of validation I and II

According to Samawati (2021), the systematic presentation of material concepts in learning products must be sequential, correct and appropriate. This aims to avoid misconceptions about the concept of chemical thermodynamics. If the understanding of a prerequisite concept is wrong, it will have difficulty and even misconceptions in learning the next concept (Aisyah 2023). Then the second validation was carried out to obtain better E-LKM results. After making revisions based on suggestions from validators, the percentage in the second validation increased to 97%. One of the improvements made is related to the thermodynamic material presented in the E-LKM. Improvements can be seen in Figure 3.



(a) (b)

Figure 3. Improvements to the material on the E-LKM (a) before validation (b) after validation.

Media validation involves 3 validators who are expert lecturers in the field of media. The purpose of media validation is to assess the PjBL-based SSI E-LKM on Chemical Thermodynamics based on aspects of display feasibility and software utilization feasibility. The percentage results of each aspect of the media validation assessment can be seen in Figure 4.

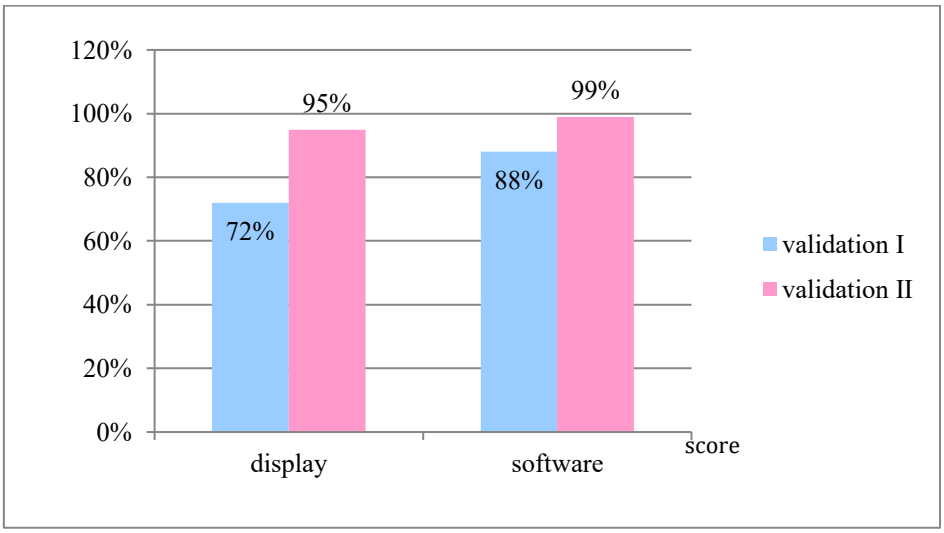
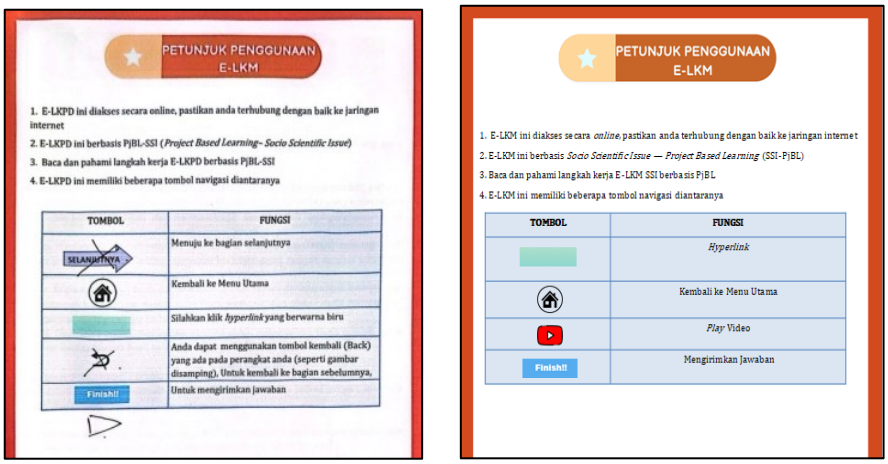


Figure 4. Results of validation I and II

The media validation stage was carried out twice. In the first validation, an average percentage of 80% was obtained with a very valid category. When viewed from the percentage value, it can be said that the E-LKM product developed has included a very valid category in terms of media. However, there still needs to be improvements to several components of the E-LKM to make it even better. In the first validation, suggestions and input from the validator were obtained to improve the PjBL-based SSI E-LKM, so the researcher made revisions and the second validation to get a better PjBL-based SSI E-LKM. After making improvements according to the validator's suggestions and input, a second validation was carried out.

The second validation obtained a percentage of 97% with a very valid category. One of the suggestions given by the validator is to improve the navigation buttons contained in the E-LKM. Navigation buttons serve to assist students and lecturers in exploring and interacting with content in the E-LKM digitally. These buttons are designed so that users can move between pages, access certain features, and complete tasks easily. The E-LKM that students work on is based on the liveworksheets website so that the accuracy of the instructions and functions of each navigation button must be correct and clear. Based on Monica's research (2023), student activity sheets must have clear and easy-to-understand instructions for use and all navigation buttons must function properly to make it easier for users to use.



(a) (b)

Figure 5. Navigation button improvements (a) before validation (b) after validation

Implementation phase

The implementation phase is the stage of implementing the developed product, namely the PjBL-based SSI E-LKM on chemical thermodynamics material in the classroom learning process. This implementation phase consists of several stages, namely one-on-one trials, small-scale trials and large-scale trials involving students to determine student responses to E-LKM teaching materials. The one-on-one test was carried out involving 3 students who had studied chemical thermodynamics material. The three students are students who have different levels of academic ability, namely high, medium and low. Based on the results of the one-on-one trial, it was found that the E-LKM could be done by students with high, medium and low ability levels, then in terms of working according to the time given, there were differences in the completion time of the E-LKM. Students who have medium and low ability levels take longer than students with high ability levels. Based on the results of the one-on-one test, comments were also obtained from students regarding the PjBL-based SSI E-LKM.

Small group trials aim to identify errors or problems that arise when the developed media is used (Wicaksana 2023). In the small-scale trial, the respondents were obtained from 2 Physical Chemistry Lecturers and 20 students by giving a small-scale trial response questionnaire. Lecturer response questionnaire data were obtained from 2 respondents, namely Physical Chemistry lecturers at the Chemistry Education Study Program at Riau University and Muhammadiyah Riau University. The results of the lecturer's response to the developed PjBL-based E-LKM SSI product can be seen in Figure 6.

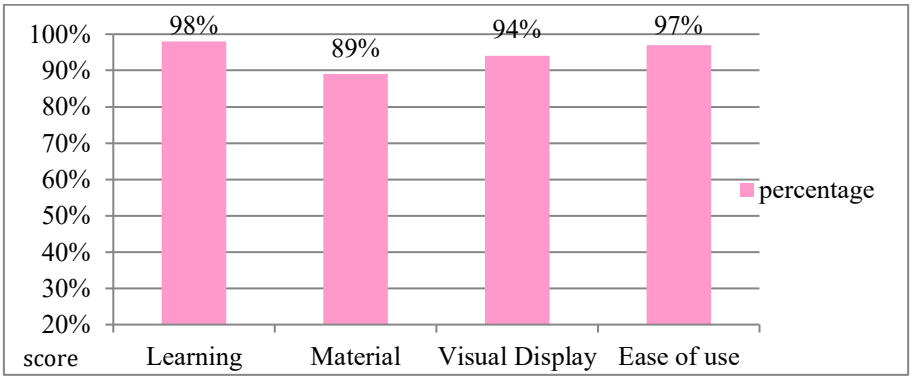


Figure 6. Physical Chemistry Lecturer Response Results

The average result of practicality based on the lecturer's response obtained a percentage value of 95% with very good criteria. Based on this value, it can be stated that the product developed has very good and practical criteria. In addition to the percentage value obtained from the lecturer's response, feedback was also obtained on the chemical thermodynamics E-LKM that had been developed. Student response questionnaire data were obtained from 20 students of the Chemistry Education Study Program semester V as respondents. Researchers gave E-LKM to students, then students were given time to see and assess the E-LKM by filling out a student response questionnaire. The results of student responses to the PjBL-based E-LKM SSI product on chemical thermodynamics material developed can be seen in Figure 7.

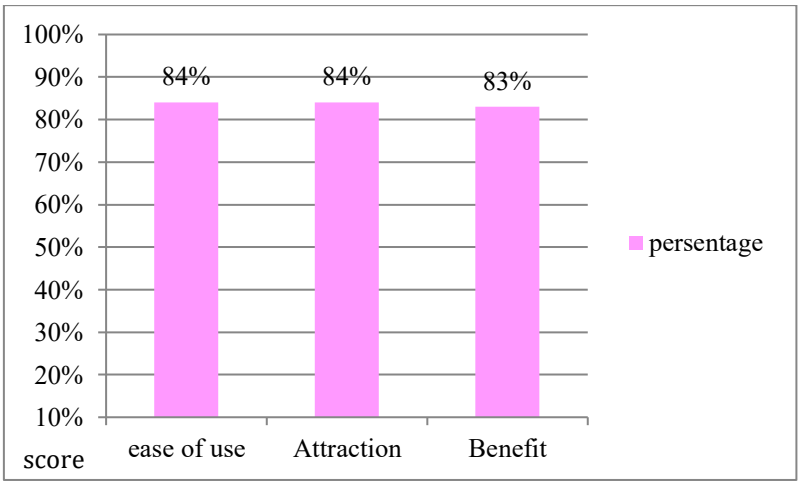


Figure 7. Student response questionnaire results

The three aspects for assessing the attractiveness of PjBL-based SSI E-LKM by chemistry education students showed a very good category, with an average percentage of 83.6% out of 100. The results shown in Table indicate that PjBL-based SSI E-LKM makes it easier for students to learn because it can be accessed via mobile devices and laptops, has an attractive appearance and is very useful in learning.

Evaluation phase

The evaluation stage in this study was carried out at each stage of ADDIE. Evaluation aims to analyze the data obtained from the results obtained from each stage of the research, namely at the analysis stage, starting from the initial analysis, students, curriculum and materials, to map the problems and solutions offered. The evaluation carried out at this stage is the adjustment of learning indicators and materials to be included in the ELKM. The design or planning stage also evaluates the quality of teaching materials, product design and material preparation. The evaluation carried out is the adjustment of indicators on each instrument of the teaching material quality assessment sheet. In addition, improvements were also made to the materials to be presented in the E-LKM. So that before entering the development stage the material framework and assessment instruments are correct.

Evaluation at the development stage is carried out during product validation by material and media experts in accordance with the suggestions and input provided by the validator. The implementation stage is the one-on-one trial stage, limited trials and field trials. Based on input from lecturers and students on small-scale trials, researchers re-evaluated the products that had been developed to improve the products that had been developed. The final results of the evaluation stage show that the product developed in the form of E-LKM is declared valid and gets a good response from lecturers and students.

4. Conclusion

Based on data analysis and discussion, it can be concluded that the Electronic Student Activity Sheet (ELKM) SSI based on PjBL can be developed using the ADDIE development model and using the liveworksheets website. The E-LKM SSI based on PjBL is declared very valid or very feasible to be used in the learning process based on the assessment of material experts and media experts, where the validation of the material is assessed as very valid and the validation of the media is assessed as very valid. very valid assessment. The E-LKM that was developed received a response from lecturers with a very good assessment and from students it was assessed as interesting so that the E-LKM is practical and interesting for students. The E-LKM is feasible to be used in the physical chemistry learning process.

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