



Development of Electronic Modules Based on Collaborative Problem Solving on Buffer Solution Materials

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Abstract: The aim of developing an electronic module based on Collaborative Problem Solving is to determine the characteristics and quality of an e-module based on *Collaborative Problem Solving* on buffer solution material. This research is motivated by the lack of learning processes that utilize *e-learning*; one e-learning application is electronic modules based on *Collaborative Problem Solving*. This development research design uses the 4-D model, namely *Define, Design, Develop, and Disseminate*. The type of data obtained is qualitative data, which contains interview results, comments, suggestions, or input regarding the development of electronic modules. In contrast, quantitative data is obtained using questionnaire scores, which include four categories, namely strongly agree, agree, disagree, and strongly disagree. The quality of electronic modules is assessed based on expert assessments, chemistry teacher assessments, and student assessments. The results of the expert assessment were 96%, the Quality Assessment by the Chemistry Teacher was 86.77%, and the Student Assessment was 81.94%, obtaining very high validity results, so it can be concluded that the development of electronic modules can be used in schools on buffer solution materials.

Keywords: Buffer solution; Collaborative problem solving; Electronic module

Introduction

The development of science and technology, which is increasingly dynamic and undergoing updates all the time, requires us to remain able to answer these challenges. The world of education faces challenges in curriculum development in the 4.0 era, where it must produce human resources with new literacy abilities, namely data literacy, technological literacy, and human literacy, that pivots on noble morals (Suryaman, 2020). The free learning curriculum currently being implemented in education will always be connected to the role of technology in it.

System educational learning in general until currently, is still dominated by the lecture method. Where there are not so many of these methods develop students' thinking abilities, especially in solving a problem. Often found in teacher learning only using a monotonous method, where In this method the teacher only provides material through lectures, giving

assignments, and free discussion. So the teacher can't develop interesting learning. There is the impression that teachers are afraid to design learning themselves, from learning materials to methods evaluation there is almost no difference (Syaparuddin et al., 2020). Learning outcomes are the result of various activities carried out, and a lot of effort carried out to improve learning outcomes. Especially if confronted At this time where many people mention the disruptive era, of course with The various existing disturbances increasingly affect the world of education and what is related to it. In it, you must be able to anticipate how learning outcomes can be achieved quickly (Wiradintana, 2018). Learning is the driving force within students to able to achieve optimal learning outcomes so that the desired goals in learning can be achieved achieved (Budiariawan, 2019).

Educational personnel is an essential variable in education, as science and technology have developed a lot and have a positive impact by being facilitative (making it easier). However, the professionalism of

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educational personnel must be improved by providing a variety of tools to increase the effectiveness of the learning process (Lestari, 2018). The role of technology in the world of education today is very close and grows simultaneously. This is proven by using smartphones, which can be used as educational facilities.

Using information and communication technology in learning can support and develop students' cognitive, affective, and social skills. The biggest factor that creates a less supportive learning environment for students, namely noise when students are present carrying out learning activities, monotonous learning atmosphere (Hanina et al., 2021). Technological developments in general has had a massive influence all aspects of life (Rosmalinda et al., 2023). Therefore, learning resources are one of the factors that make students understand concepts and material well. One of the teaching materials that can be applied in the learning process is an electronic module (*e-module*) because the use of *e-modules* allows students to learn independently. Electronic modules or *e-modules* present independent learning materials arranged systematically into minor learning units to achieve specific learning objectives. They are presented in electronic format, which includes animation, audio, and navigation, which makes users more interactive (Prayudha et al., 2017).

Modules are teaching materials that an educator can develop in carrying out the learning process. *E-modules* are included in interactive learning media because, in one module, there is material, animation, and evaluation that can provide direct assessment to students. Meaningful learning can be realized through modules, which interact and communicate between learning actors to improve learning outcomes (Mulyono et al., 2023). The material in *the e-module* is connected to students' daily lives so that they can better interpret every event in everyday life.

Chemistry is a compulsory subject in Senior High School. For high school students, especially students new to this subject, chemistry is complex, so students feel less able to learn it. Students' difficulties in studying chemistry can originate from difficulties understanding terms numbers, and dealing with chemical concepts (Arifin, 1995).

One material that instills many concepts is buffer solution material, where students must understand the properties of buffer solutions and the working principles of buffer solutions. Buffer solution material is material that requires students to have good mastery of concepts and mathematical skills. In conjunction with this, continued research is needed on how students become successful problem solvers. This may relate directly to the information processing model (Gabel, 1999). In this process, there will be an increase due to the centered

problem-solving model (Putri et al., 2020). Learning by applying PBL will be able to train students to solve problems (Lathifah et al., 2020). The Collaborative Problem Based Learning learning model helps teachers create a learning environment that begins with important and relevant issues for students correlated with increased capabilities (Zulkarnain et al., 2019). The importance of CPS is increasing with the complexity of human social systems and the problems to be solved (Graesser et al., 2018). CPS might help to develop learning designs and tools that facilitate effective metacognitive monitoring and self-regulated learning (Dindar et al., 2020). CPS may impart collaboration skills in youth (Gauvain, 2018).

One material that instills many concepts is buffer solution material, where students must understand the properties of buffer solutions and the working principles of buffer solutions. Buffer solution material is material that requires students to have good mastery of concepts and mathematical skills. The results of observations carried out at Senior High School 4 Yogyakarta show that students often become passive when learning chemistry taking place. Often educators deliver material via powerpoint considered less effective because it only conveys an outline of the material taught and there is no evaluation at the end of the lesson, so participants Students cannot measure the extent of their understanding of the material delivered. Meanwhile, teaching materials are used in the form of printed books and worksheets. Of course, it has limitations, namely that it can only contain material in the form of text and images and is less developed in the current technological era, so the media used by educators in the learning process is assessed as less interesting making it difficult for students to understand the material taught. Therefore, learning media is needed that can be interesting students' attention which includes problem solving and evaluation interactive. Modification of this learning media is really needed to be able to do it make students more active in the learning process, and make modifications needed to adapt to current technological advances because of technology considered capable of being an important tool in improving performance, collaboration, experiences and learning outcomes.

Therefore, based on the problems above, developing interesting e-modules can be a solution for creating a learning atmosphere that involves students actively thinking and discovering. The e-module on buffer solution material is a teaching material designed systematically and structured to facilitate chemistry learning. Modules can be developed by educators themselves so that they can be adapted to the characteristics of students. Apart from that, module development can answer or solve problems or difficulties in learning.

Method

Research and Development (R&D) development research. *Development research* is a research method used to produce specific products. The development model is the basis for developing the product that will be produced. The development model used in this research is the *4-D development model (four-D model)*. The *4-D* development model was developed by Thiagarajan et al. (1974). This model has four stages: First, *define*; Second, *design* (planning); Third, *develop* (development); and fourth, *disseminate*. The data type obtained is qualitative data, which contains interview results, comments, suggestions, or input regarding developing electronic modules.

This method is used to produce products and test the effectiveness of these products (Fitri et al., 2023). In contrast, quantitative data is obtained using questionnaire scores containing four categories: strongly agree, agree, disagree, and strongly disagree (Mardiah et al., 2018). The data obtained was then changed by giving a score to each category for each item (Izzati, 2017). The score given is determined by the Method of Summated Ratings (MSR), a scoring method for attitude statements that uses distribution to determine the scale. To get the eligibility percentage, the formula used is:

$$p = \frac{n}{N} \times 100\% \tag{1}$$

Where P is the percentage of validation test results, n is the total score of the expert assessment and N is the maximum score that should be obtained (Sriwahyuni et al., 2019). Percentage calculation results validity that has been obtained can then be converted to assessment statement (Nengsih et al., 2023). The criteria used refer to the eligibility criteria with the criteria being very feasible, feasible, quite worthy, less worthy, and very less worthy (Yuliana et al., 2023). The validity results whose percentages are known can be interpreted as follows:

Table 1. E -Module Validation Interpretation

Percentage	Interpretation
0%-25%	Very not good
26%-50%	Not good
51%-75%	Good
76%-100%	Very good

Based on this interpretation, the electronic module can be said to be successful and valid if a score of 56%-100% is obtained.

Results and Discussion

Define Stage

This stage is a study introduction in which the researcher analyzes the need for teaching materials needed in school environment, as well as content preparation material that will be written in the module (Azizah et al., 2023). Teacher activity is very important to analyze so that the learning process can run optimally. Teachers must make the learning process active and fun so that students are motivated to follow the learning process (Ariyanti et al., 2024). Effective learning can be carried out if the teacher able to provide clear information to students so students can easily understand it (Somayana, 2020).

The define stage produces a basis for product development and defines the needs-based requirements for developing *e-module products* based on *Collaboration Problem Solving* (Mardiah et al., 2018). CPS enables students to invest most of their time when designing and developing problem-solving strategies through activities such as improving and formulating plans (Sriwahyuni et al., 2019).

The data collected and defined in product development is initial data obtained from interviews, where the results of the interviews can be concluded that the use of technology-based learning media is still very lacking and limited, so media is needed that can help educators and students in their learning process. The results of the interviews conducted are presented in Table 2.

Based on the Table 2 of the interview, it can be concluded that media is needed that can attract students' attention. The media presented is integrated by CPS which is able to increase cooperation and problem solving. In particular, in the case of such learning where the module can function as a tutor for students, human relevance interaction analysis has been recognized (Rojas et al., 2021).

The module developed must be able to improve problem solving because Problem-solving skills are very important in the learning process. To complete the project, students need to overcome all difficulties, and their problem-solving skills will gradually become better and more meaningful (Hidayatullah et al., 2020). In the case of collaborative problem solving, it is valuable to parse social skills from cognitive skills (Stoeffler et al., 2019). Apart from that, teachers must also be able to build good communication through interesting learning media (Hanina et al., 2021). Media is able to stimulate students to learn (Lubis et al., 2021).

Table 2. Interview Results at Senior High School 4 Yogyakarta

Question	Answer
How do you implement the curriculum? Do you use the revised K13 Curriculum or use the Merdeka Curriculum?	The implementation of the curriculum at SMAN 4 Yogyakarta is carried out in stages, where class X applies the Merdeka curriculum and class XI and class XII apply the K13 curriculum.
Are there any obstacles to using the curriculum?	The implementation of the curriculum goes well and students gain a lot of learning experience.
How will the learning process take place after offline learning is implemented again?	Learning initially requires deep understanding by students because they are required to adapt as quickly as possible to existing conditions. So it requires teaching staff to take more initiative in the learning process.
What learning methods are used, are there any obstacles in them?	The learning method used is the lecture method.
What learning model is used, are there any obstacles in it?	The model used depends on the material being taught, but what is often used is the Discovery Learning model. The obstacle found is that students are less active in discussing.
Are learning media often applied?	Learning media is rarely applied because students are less active in searching independently.
What learning media have been applied in the learning process?	The learning media that is often applied is power point or worksheets.
Have you ever implemented e- learning modules?	Never.
In your opinion, do e- modules based on Collaborative Problem Solving be effective if implemented in schools?	The use of e- modules based on Collaborative Problem Solving will be effective if they are made as interesting as possible so that students are able to discuss more actively to solve a stimulus or problem.

Design Stage (Planning)

The stage aims to design the media and instruments used in research, media selection, format selection, and initial design (Mardiah et al., 2021). The design stage is carried out to design the product being developed in the form of a chemical e-module (Yuliana et al., 2023). The researcher made an initial framework design preparation of products with pay attention to media selection software that will be used in create electronic modules, assign electronic module preparation format, and designed the initial framework of manufacture of electronic modules (Surtini et al., 2023).

Designing a teaching module is the first step in the design process which greatly influences subsequent stages (Fitri et al., 2023). The planning stages for the product being developed are well structured and directed. At this stage, product planning is carried out to be developed in the form of a flowchart. The *flowchart* results in making electronic modules can be seen in Figure 1.

Based on the flower chart, the next step is to select media to support the e-module development process (Mardiah et al., 2021). The module is designed based on the stages of collaborative problem solving. In the stages are that students feel that it is easier for them to understand the lesson with PBL steps such as group discussions, presentations, giving responses and so on determine a solution strategy. PBL helps students develop thinking critical to solving problems in their clinical settings, and bridging the gap between theory and practice (Lathifah et al., 2020). Problem solving

makes students able to know something they don't know yet (Kim et al., 2021).

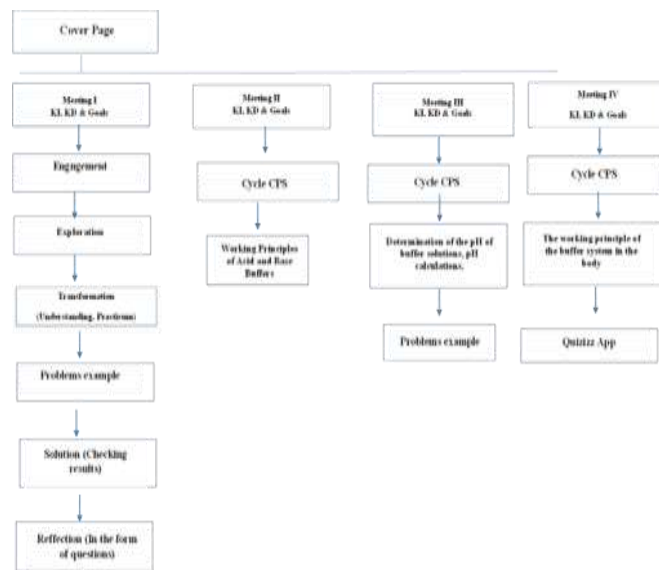


Figure 1. Flowchart e-module

At the product development stage, the initial design in the form of cover, and contents are designed using Canva and Picart, then insert several videos into the design and edit using Wonder share Filmora 9, then at the end of the e-module there is a quiz using the quizizz application. Modul electronic with CPS occurs when two or more people engage in a coordinated attempt to solve a problem (Vrzakova et al., 2020). Collaboration is understood as an unequivocally

interpersonal and contextual phenomenon, we argue that the role of an individual interacting with themselves (Dowell et al., 2020). Effective collaboration is achieved when individuals regulate their team members' performance and their own performance through productive interactions (Dindar et al., 2020).

The application used is Flip PDF Professional, Professional PDF is able to make the appearance of electronic modules more attractive, by adding animation when opening each page, and being able to add audio, this is considered capable of attracting attention because it produces an attractive design and is not boring like the usual PDF. Forward that students have a more enjoyable learning experience, which is able to make them more interested in the material, the use of professional PDFs is also able to make students not bored in reading because of the interesting impression, to the module which can help to display real learning (Sriwahyuni et al., 2019). The results of the electronic module design using Flip PDF Professional are as follows:

a) Cover View



Figure 2. View of the e-module cover

b) Initial Material Display



Figure 3. Display of initial e-module material

c) Display of Example Questions



Figure 4. Example of an e-module question

Develop Stage (Development)

Theoretical validation by expert lecturers

This stage is implemented assessment by validators consisting of validation material and media validation is then carried out revision stage according to suggestions from the validator (Shabrina et al., 2023). This feasibility assessment is purposeful to find out whether an electronic module is suitable or not (Shafira et al., 2023). Products created, including electronic modules, learning tools, and research instruments, are validated by experts by providing suggestions and criticism of electronic modules and learning tools previously developed. The results of theoretical validation are that the e-module is suitable for use with revisions. Following are the validation results in Table 3.

Table 3. Expert Theoretical Validation Results (Gregory et al., 2000)

Validator	Irrelevant	Relevance Relevant
1	0	27
2	1	26

The validation results then calculated the level of validity to obtain a validity of 0.96. The interpretation of validity in Table 4 is as follows:

Table 4. Validity Level (Sugiyono, 2018)

Coefficient	Validity
0.8-1.0	Very high validity
0.6-0.79	High validity
0.4-0.59	Medium validity
0.2-0.39	Low validity
0.00-0.19	Very low validity

All of the instruments that have been validated can be directly used in the learning process (Lestari et al., 2021). So, the validation obtained after being interpreted has very high validity with a value of 0.96.

Electronic Module Quality Test Results

The Problem Based Learning (PBL) learning model helps teachers create a learning environment that starts with issues that are important and relevant to students, and allows students to gain more learning experience (Suswati, 2021). The quality test results of learning products, namely electronic modules based on *Collaboration Problem Solving*, were assessed by five chemistry teachers in Yogyakarta, namely teachers at SMA Negeri Senior high school 4 Yogyakarta, Senior high school 5 Yogyakarta, Senior high school 7 Yogyakarta, Senior high school 10 Yogyakarta, and Senior high school 9 Yogyakarta.

Table 5. Quality Assessment Results by Chemistry Teachers

Aspect	Average	Ideal Percentage (%)	Category
Material/content	4.32	86.4	Vg
Presentation techniques	4.66	93.33	Vg
Language	4.26	85.33	Vg
Software engineering	4.06	81.33	Vg
Audio visual display	4.6	92	G
CPS	4.2	84	Vg
Characteristics of electronic modules	4.05	81.14	G
Total		86.77	Vg

Based on Table 5, the quality of the *e*-Module can be said to be good with the highest percentage of ideality being in the second indicator, namely presentation technique, where the presentation technique is carried out by providing a link which is a link from the electronic module, so that teachers can access it wherever and whenever.

Test Student Readability

Electronic module products assessed by teaching staff from various schools in Yogyakarta are then tested for readability by students on electronic modules based on *Collaboration Problem Solving*. Product readability includes learning and display aspects. The readability results of electronic module products based on *Collaboration Problem Solving* can be seen in Table 6 as follows:

Table 6. Product Readability Results by Students

Assessment Aspects	Average	Ideal Percentage (%)	Category
Material	4.02	80.41	VG
Ease of Use	4.15	83.03	VG
Appearance	4.11	82.38	VG
Total		81.94	VG

Based on Table 6, it shows that students' readability of the electronic module based on *Collaboration Problem Solving* as measured from the aspects of material, ease of use and appearance is very good with an average ideal percentage of 81.94 with very good validity. Based on the results obtained, the module developed can be used in the learning process. In accordance with the results of research carried out by Nisa et al. (2020), it was found that e-modules are a learning resource that makes things easier for students learn and can improve abilities. The module developed is able to attract students' attention in discussions because it has various features that facilitate problem solving and student collaboration. Additionally, our findings confirm that in collaborative discussions, if the knowledge construction level is in sharing and comparing views (Zheng et al., 2020). They can exchange opinions and ideas (Ouyang et al., 2021). The module used the CPS steps in the current study primarily included cognitive behaviors realized through verbal interactions (Nguyen et al., 2022).

The audio-visual capabilities of the online problem sets facilitated the integration of color images and YouTube videos, important for connecting microscopic and macroscopic representations, and highlighting the interconnectedness of chemistry. Next, the online space streamlined and enabled in-the-moment feedback and students during workshops (Gemmel et al., 2020). Based on research, problem solving-based modules are able to attract students' attention (Suswati, 2021).

Based on Cooper et al. (2008) the most significant result of this research, students maintained their improved strategies and were better at dealing with problems problem solver when working alone after being part of a group. Collaborative problem solving (CPS) has been receiving increasing international attention because much of the intricate work in the modern world is performed by teams (Stadler et al., 2020).

Conclusion

This electronic module is also easy to use and can be used offline with a PC or *Android device*. Electronic learning modules are equipped with animated videos that can be accessed offline, allowing students to learn independently wherever and whenever they want. At the end of the electronic module is an evaluation section, which allows students to self-evaluate online and quickly determine whether they are right or wrong. The electronics module is based on an expert assessment of 96%, a quality assessment by chemistry teachers of 86.77%, and an assessment by students of 81.94%.

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Author Contributions

Conceptualization; AKSK.; validation, DP.; formal analysis, AKSK.; investigation, AKSK.; data curation, AKSK.; writing – original draft preparation, AKSK.; writing – review and editing, DP.; Supervisor; DP.: visualization, and T. R. and R. A. E. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest regarding the publication of this article.

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