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Research Article

Development of interactive teaching materials based on inquiry based learning models based on the outcome-based education curriculum in analytical chemistry learning

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Keywords

Analytical chemistry
e-modules
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Volumetry

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Abstract

This research to develop an IBL-based electronic e-module integrated with the OBE curriculum in analytical chemistry learning. This research is a development research using the ADDIE model which consists of 5 stages: Analysis. Design, Development, Implementation and Evaluation. The sampling technique uses purposive sampling as many as 28 preservice chemistry teachers. Research data were obtained from a validation questionnaire for media experts, material experts, linguists and student responses to the developed e-module with BSNP criteria. Material expert validation obtained an average content feasibility of 3.22, language eligibility 3.52 and presentation feasibility 3.73 IT expert validation obtained an average for design indicators 3.75, display 3.75 and visual 3.3 and usage 3.75. Student response to learning using an electronic IBL-based e-module integrated with the OBE curriculum for display is 89.99%, content quality is 92.85%, usage is 93.3% and usefulness is 93.15%. Implementation of interactive e-module products based on inquiry based learning in learning that can improve student chemistry learning outcomes in the Analytical Chemistry course with Gain 81.20.

Introduction

The quality of education in Indonesia at this time was still relatively low data from the Nations Development Program regarding the value of the Human Development Index (HDI) in 2020, Indonesia is in 107th place out of 189 countries (UNDP, 2020). Even though there has been an increase from year to year as shown by Indonesia's HDI value of 0.703 in a row in 2016; 0.707 in 2017; 0.712 in 2018; 0.718 in 2019; and 0.718 in 2020, but this increase is still not significant and tends to be stagnant (UNDP, 2020). Because the HDI value is interpreted as a measure of progress in the quality of education, health and income of a country, this stagnant pattern indicates that the quality of education in Indonesia is still as low as in previous years. This certainly needs the attention of many parties.

The fact of the low quality of Indonesian education nationally along with the quality of Indonesian science education is quite concerning. Based on the average score of the National Examination (UN) in Science subjects in the last four years, there is a downward trend. Especially in the Chemistry subject, the trend of decline can be seen from the average UN Chemistry score of 54.49 in 2016; 53.82 in 2017; 51.14 in 2018; and 50.91 in 2019 (Kemdikbud, 2019). Especially in 2019, Analytical Chemistry is a sub-section of the chemistry subject that gets the lowest average score, namely 43.87 for UNBK and 39.17 for UNKP. The downward trend in the average National Examination score and the low score in Analytical Chemistry shows that the level of mastery of science in Indonesia is still low. This is in line with Gultom's (2019) explanation about the lagging behind Indonesia's science education from other countries so that a re-evaluation of the current subject curriculum is needed in order to prepare a resilient generation to face the Industrial Revolution 4.0.

Based on the results of case studies at universities in North Sumatra in basic analytical chemistry and qualitative and quantitative analytical chemistry courses in the last two years it has not been optimal. This is known from the final test scores of preservice chemistry teacher who received only 12.62% A grades, 10.19% C scores and 4.85% E scores. In this regard, efforts are needed to improve the quality of learning with learning models that are capable equip and activate knowledge in preservice chemistry teachers that they can foster thinking skills and strengthen concepts to achieve basic competencies in Analytical Chemistry material. Thus, the ability to think creatively, critically, collaboratively and communicatively and student teacher candidates can be trained in a scientific attitude when discovering facts, concepts and theories as well as Outcome-Based Education (OBE) (Lawson, 2010; Tawil and Liliasari, 2014).

Efforts that can be made to overcome this problem are to provide electronic e-modules that are based on inquiry-based learning integrated with the OBE curriculum. Interactive electronic modules can increase students' interest in learning so as to improve student learning outcomes. E-modules can be studied independently, so students become more active (Silaban et al. 2022; Purwaningtyas et al., 2017). Not only that, electronic e-modules are also interactive and can present material with multimedia displays such as videos, animations, simulations, tests which allow for direct feedback (Sugihartini and Jayanta, 2017).

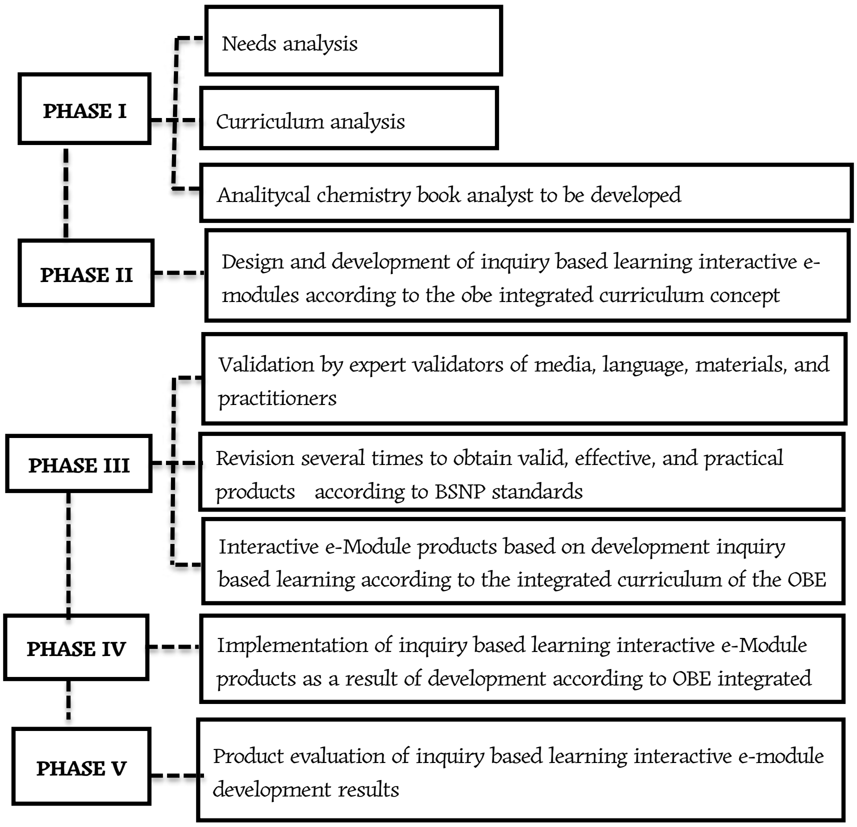

Fig.-1. Applied product research flowchart (Cahyadi, 2019)

OBE is outcome-centered education, not just the material to be completed. OBE measures learning outcomes (outcomes) and enables students to develop new skills that prepare them on a global level (Davis, 2003; Latif, 2021). With interactive e-modul based on inquiry-based learning in accordance with the integrated OBE curriculum concept that is valid, effective, and practical, students will be motivated to be more proactive in interacting, collaborating, and innovating in constructing their knowledge and skills, so that student competency is expected to increase with superior, qualified, productive, capable and skilled graduates in managing learning with a responsible attitude in the world of work to become a professional teacher.

The aim of this research is get data on the feasibility of analytical chemistry teaching materials in the form of interactive e-modules based on standard inquiry based learning in Analytical Chemistry courses with reference to the OBE curriculum concept, to obtain an interactive e-module based on inquiry based learning which refers to the valid, effective and practical OBE curriculum according to BSNP standards, and determine the application of interactive e-module products based on inquiry based learning in learning that can improve student chemistry learning outcomes (Gain scores) in Analytical Chemistry courses.

Method

This type of research is educational research and development (Educational Research and Development), using the ADDIE method (Mulyatiningsih, 2013; Islamiyah et al., 2022; Asmi et al., 2023; Fitri et al., 2023; Siregar and Silaban, 2023). This research is planned for one year, to be carried out at the Department of Chemistry, Medan State University. Visually, the stages of the ADDIE Model in development research to produce a product for developing a textbook compilation of Graph Theory can be seen in Fig.-1.

This research is a research and development education research. The development model used is ADDIE which includes 5 stages, namely Analysis, Design, Development, Implementation and Evaluation. This research was conducted at the Unimed Chemistry Faculty from March 2023 – November 2023. The sample in this study was 28 preservice chemistry teachers. Sampling was done by purposive sampling. Data analysis techniques Validation test of the team of profesional judment on material and media aspects with BSNP standards and student response questionnaires.To find out the increase in learning outcomes can be calculated by the g factor formula or normalized gain score (Syafitri and Tressyalina, 2020).

Results and Discussion

The method use in this research is research and development (R & D) method with development model of ADDIE (analyze, design, development, implementation, evaluation). This model is structured programmatically with sequences of systematic activities in the effort to solve learning problems related to learning resources that match the needs and characteristics of learners. The ADDIE model consist of five steps: (1) analysis, (2) design, (3) development, (4) implementation, and (5) evaluation (Tegeh et al., 2014). The results of the research based on the ADDIE research model can be described as follows.

Analysis Stage

The first stage in the ADDIE model research is analyze. At this stage it aims to identify the problems faced by lecturers in the learning process. The analysis carried out was to find out information related to the use of teaching materials, learning models, analytical chemistry learning outcomes during learning activities.

Based on the explanation above, it is necessary to develop electronic teaching materials based on inquiry-based learning so that they can improve students' analytical chemistry learning outcomes. This is also in accordance with the statement in which the two chemistry lecturers stated that it was necessary to develop inquiry based learning electronic teaching materials to motivate students according to their needs. After that at the stage of analyzing preservice chemistry teacher needs, the researcher distributed questionnaires so that information could be obtained regarding students' preferences in learning analytical chemistry, learning methods of difficulties encountered, teaching materials owned and introduction to e-modules so that teaching materials were developed according to student needs. The questionnaire was given in the form of a google form.

In accordance with the results of the questionnaire, it can be seen that the teaching materials most used by lecturers and students during the learning process are textbooks. As many as 64% of students have never seen and used electronic e-modules and 50% of students have never used e-modules in the learning process. Based on the data above, it is necessary to develop electronic e-modules based on inquiry based learning. This is also in accordance with the results of the initial needs analysis for lecturers, so that the development of electronic e-modules based on inquiry based learning can improve analytical chemistry learning outcomes and motivate student learning.

Design Stage

Based on the results of the initial analysis stage, this research was continued to the inquiry-based learning-based e-module product design stage. At this stage, some of the activities carried out by researchers are: (1) Select supporting applications for the creation of inquiry-based learning e-modules. The application used is web-based; (2) Develop an initial format of electronic e-module based on inquiry based learning. The initial format or design of the e-module is presented in the form of a flowchart. Making a flowchart aims to make the product developed have a clear navigation flow and make it easier for users to use it; (3) Collect references related to analytical chemistry material as the content of the developed inquiry based learning e-module. The materials used are gravimetric, volumetric, acid-base titrations, redox titrations, precipitation titrations and complexometric titrations; and (4) Develop electronic e-module designs and features based on inquiry based learning. The arrangement of designs and features is adjusted to the characteristics of a good electronic e-module that fulfills three requirements, namely didactic, constructive and technical.

Development Stage

At this stage the researcher develops the product in accordance with what has been done at the design stage. The application used to make this teaching material is web-based. This link can be accessed using laptops, smartphones and notebooks so that it can be done anywhere and anytime without being limited by space and time. Inquiry-based learning-based e-module products that have been developed are then subjected to a feasibility assessment or validity test by two chemistry education lecturers as material experts and IT experts using validation instruments in accordance with the developed BSNP. Suggestions and comments given by the validator during the validation test are used as material for improvement or revision of the initial product so that the final product is deemed feasible to be implemented in learning (Asri and Dwiningsih, 2022).

Results of e-module Product Validation by Material and IT Experts

The e-module assessment was carried out by material experts covering aspects of content feasibility, language eligibility, and presentation feasibility. The material expert validators were two Unimed Chemistry Education lecturers. In detail, the material expert's assessment can be seen in Fig-2.

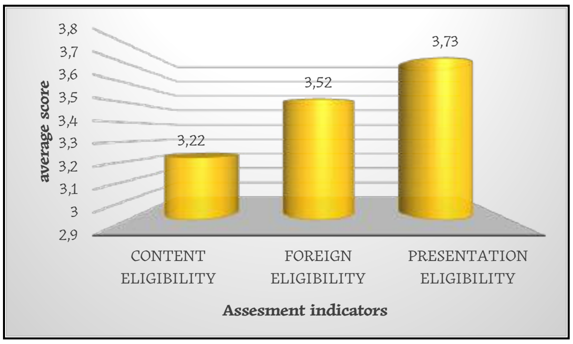

Fig.-2. Assessment of the validation of teaching materials by the validator

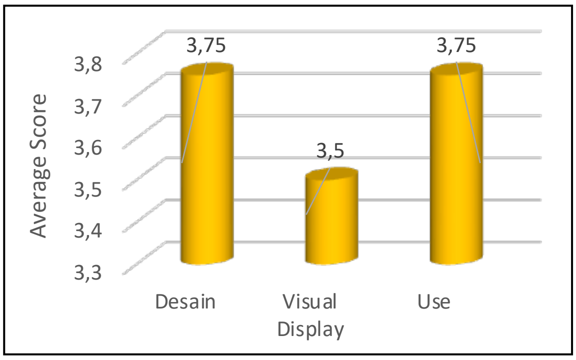

Fig.-3. Validation assessment by IT experts

The assessment carried out by IT experts includes design, visual appearance and usage. In detail, the results of the IT expert's assessment can be seen in Fig.-3. Based on the results of the assessment by IT experts above, it can be concluded that the product developed is suitable for use in the next stage.

Product Development Results e-module

The inquiry-based learning-based electronic e-module that was developed is feasible to use based on validation results from both material validators and IT experts. In the following, a display of the final results of inquiry-based learning-based e-module development is presented. The following can be seen the cover of interactive analytical chemistry teaching materials based on development inquiry based learning that are designed and developed online on the web: https://dwndnt.github.io/Modul_kimia_analitik/. The appearance of the cover and back of the e-module that has been developed is presented in Fig.-4a and Fig.-4b.

a b

Fig.-4. a. The front cover of the developed e-module; b. The back cover of the developed e-module

Implementation Stage

After the product is categorized as valid and suitable for use based on the validator, the researcher can carry out the implementation stage at the Faculty of Mathematics and Natural Sciences, the Unimed Chemistry Education Department even semester 2022/2023 PSPK 21D as many as 28 people who are taught with e-modules based on inquiry based learning. As an initial stage, a pretest was carried out to determine the extent of students' initial understanding of quantitative, gravimetric and volumetric analytical chemistry. However, previously the pretest question instrument provided had been validated and tested first.

In the large group trial, 28 chemistry education students were conducted. Improved student learning outcomes can be seen from the N-Gain. The effectiveness of interactive e-Module teaching materials is obtained from learning outcomes and analyzed using SPSS (Istuningsih et al., 2018). Data from the trial results are presented in Table 1 and Fig.-5.

Table-1 The average N-Gain is normalized in the e-module implementation

Group	Average		N-*Gain*	Criteria
	Pre-Test	Post-Test		
PSPK 21D	44.89	89.64	81.20	High

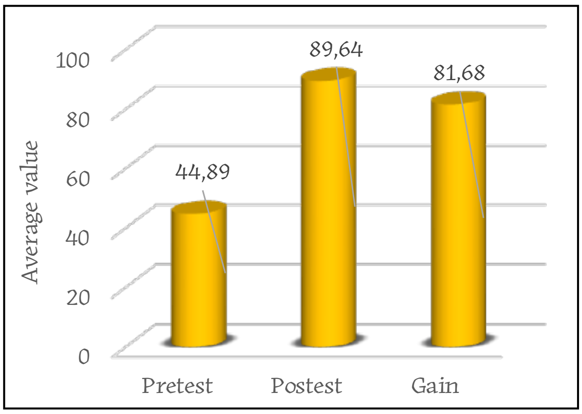

Fig.-5. Average student learning outcomes

Perceptions of Student Satisfaction Levels on the e-Module

After students use inquiry based learning interactive e-Module teaching materials, the next stage is given a response questionnaire to determine the level of student satisfaction with the use of the interactive e-Module. Response questionnaires were given to 28 students to provide responses to 20 item indicators of questionnaire statements on e-Module teaching materials developed in inquiry-based learning. From the responses collected, the percentage of student perceptions of its application and work on student worksheets in the interactive e-Module was calculated. The acquisition of perceptions of student satisfaction levels is summarized the average percentage value of perceptions of student satisfaction with interactive e-module teaching materials based on inquiry based learning development results in learning ranges from 89.99% -93.30% for each statement questionnaire, and overall the average percentage value student satisfaction level was obtained at 92.32%.

Results of Student Activity Assessment Making Discovery

Assessment of student activity is carried out by three observers/observers using performance assessment instruments when students carry out practicums according to the inquiry based learning syntax including orientation, conceptualization, investigation, discussion and concluding (Chu et al., 2017). This discovery activity was carried out for six lecture materials including gravimetry, volumetric, acid-base titration, redox titration, precipitation titration (argentometry) and complex formation titration (complexometric).

Fig.-6 shows students carrying out the activity of calculating the levels of lead (Pb) contained in $PbCrO_4$ precipitates gravimetrically using the inquiry based learning model. Orientation activities achieve the highest score, namely 92.96 and investigation, score 92 while conceptualization to arrange problems with phenomena according to experiments, observations and literature studies is the lowest, namely 88.21 (Juniar et al., 2020). GO is Gravimetry Orientation, where students carry out orientation towards the phenomena given in the quantitative analysis of Pb in samples. GC is Gravimetry Conceptualization, students answer problems from phenomena and organize them based on observation and scientific literacy. GI is Gravimetry Investigation, in this case students collect information in accordance with the problem formulation they create, design analysis procedures and develop strategies they create to answer these questions through observation, literature study, videos and practicums. GD is Gravimetry Discussion, in this discovery students discuss the results of the analysis and GK is Gravimetry Conclusion, students conclude the results of the discoveries they made in accordance with inquiry based learning.

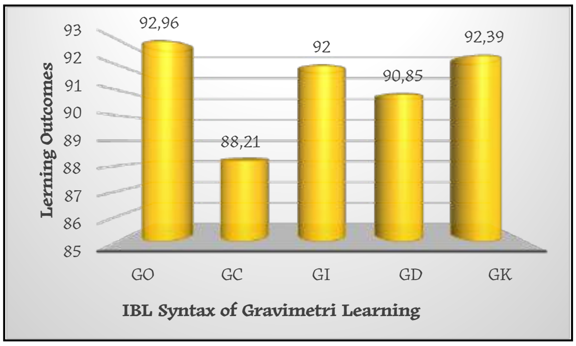

Fig.-6. Student discovery activities in Gravimetry learning

VO is volumetry oriented, in which students orient themselves toward a given phenomenon by calculating the molar concentration of primary standard solutions, secondary standard solutions, and calculating analyte levels using volumetric titration. VC is the volumetry conceptualization, students answer problems about phenomena and arrange them based on observations. and scientific culture. VI is Volumetry Investigation, in this case students gather information by formulating problems they create, design analytical procedures, and develop strategies they create to answer these questions. This question through observation, literary studies, videos and courses. Example is Volumetric Discussion (VD), in this exploration, students discuss the results of the analysis and VK is Volumetric Conclusion, students conclude the results of the discoveries they have made according to the learning method practice based on request. Discovery activities in volumetric learning are presented in Fig.-7.

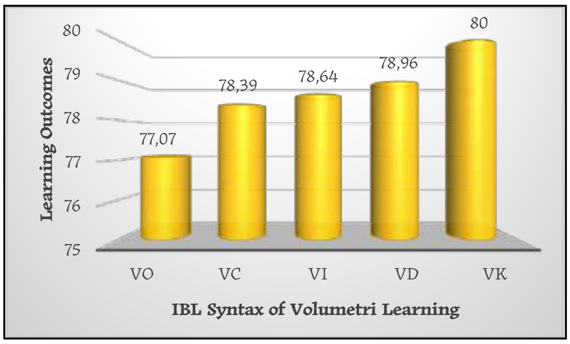

Fig.-7. Student discovery activities in Volumetri learning

The discovery activity in Fig.-7 shows that students still experience difficulties in carrying out orientation activities for determining the molarity of primary and secondary standard solutions by volumetric titration, this can be seen from the acquisition of their activity value, which is an average of 77.07. Nonetheless, in investigation and discussion activities it achieved scores of 78.64 and 78.96 and in drawing conclusions the highest was 80.

In discovery activities in acid-base titration learning, the average acquisition value of student activity in practicum is shown in Fig.-8. In Fig.-8 above, it can be seen that carrying out investigations in learning acid-base titration, namely determining the volumetric levels of acetic acid in vinegar, students obtain the lowest average value of 82.64. This is due to the difficulty of students gathering information in accordance with the formulation of the problem, designing analytical procedures and developing strategies to answer questions that arise in these discovery activities (Juniar et al., 2021).

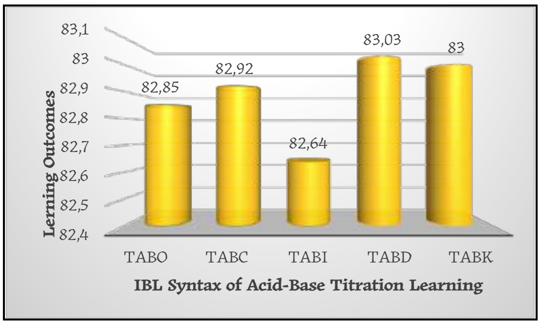

Fig.-8. Student discovery activities in acid-base titration learning

Nonetheless, in discussion activities students obtained a high average score of 83.03. TABO is Acid-Base Titration Orientation, where students carry out an orientation towards the phenomenon given in determining the level of acetic acid in a sample, TABC is Acid-Base Titration Conceptualization, where students answer problems from phenomena and compile them based on observation and scientific literacy. TABI is Acid Base Titration Investigation, in this case students collect information in accordance with the problem formulation they create, design analysis procedures and develop strategies they create to answer these questions through observation, literature study, videos and practicums. TABD is Acid Base Titration Discussion, in this discovery students discuss the results of the analysis and TABK is Acid Base Titration Conclusion, students conclude the results of the discoveries they made in accordance with inquiry based learning.

The average score obtained by students in carrying out discovery activities in redox titration learning is presented in Fig.-9. Preservice chemistry teachers practicum in discovery activity in determining chlorine levels in the phenomenon of using chlorine found in swimming pools. The conceptualization aspect makes the problem formulation of the phenomena that arise in accordance with the concept of chemistry, students get a high average score of 73.1. To do the orientation is the lowest with the acquisition of an average value of 72.39. Even so, learning activities can run well.

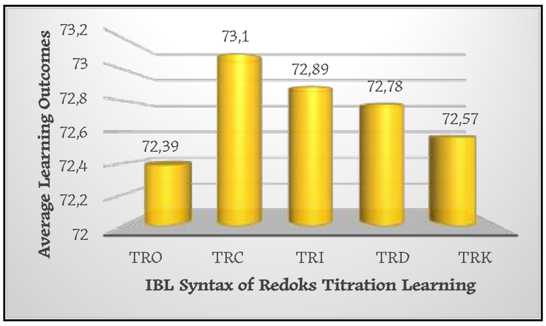

Fig.-9. Student discovery activities in redox titration learning

TRO is Titration Redox Orientation, where students carry out an orientation towards the phenomenon given in determining chlorine levels in samples, TRC is Titration Redox Conceptualization, students answer problems from the phenomenon and formulate them based on observation and scientific literacy. TRI is Titration Redox Investigation, in this case students collect information in accordance with the problem formulation they create, design analysis procedures and develop strategies they create to answer these questions through observation, literature studies, videos and practicums. TRD is Titration Redox Discussion, in this discovery students discuss the results of the analysis and TRK is Titration Redox Conclusion, students conclude the results of the discoveries they made in accordance with inquiry based learning.

Discovery activities in learning precipitation titration or argentometry can be shown in Fig.-10. TPEO is Titration Forming Precipitate Orientation, where students carry out an orientation towards the phenomenon given in determining chloride levels using Argentometry, TPEC is Titration Forming Precipitate Conceptualization, students answer problems from phenomena and arrange them based on observation and scientific literacy. TPEI is Titration of Precipitate Formation Investigation, in this case students collect information that is in accordance with the problem formulation they create, design analysis procedures and develop strategies they create to answer these questions through observation, literature studies, videos and practicums. TPED is Titration Forming Precipitate Discussion, in this discovery students discuss the results of the analysis and TPEK is Titration Forming Precipitate Conclusion, students conclude the results of the discoveries they made in accordance with inquiry based learning. Fig.-10 shows the average acquisition value of chloride determination in drinking water with precipitation titration for the discussion aspect which is the highest, namely 83.89 followed by investigation with a value of 83.57. In terms of doing orientation, the average score obtained is the smallest, namely 82.85.

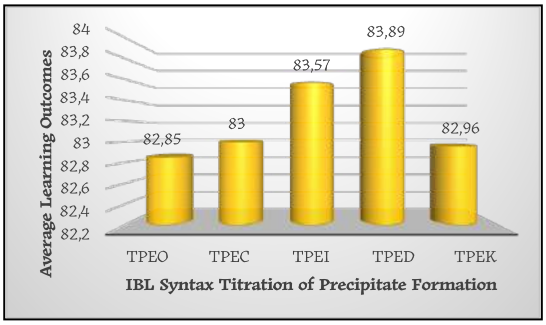

Fig.-10. Student discovery activities in titration of precipitate formation learning

Discovery activities in studying complex formation titrations (complexometric) can be shown in Fig.-11. TPKO is Orientation Complex Formation Titration, where preservice chemistry teachers carry out an orientation towards the phenomenon given in determining water hardness using complexometric titration. TPKC is Conceptualization Complex Formation Titration, students answer problems from phenomena and formulate them based on observation and laboratory. TPKI is Titration Forming a Complex Investigation, in this case preservice chemistry teachers collect information in accordance with the problem formulation they create, design analysis procedures and develop strategies they create to answer these questions through observation, literature study, videos and practicums. TPKD is Titration Forming Complex Discussion, in this discovery students discuss the results of the analysis and TPKK is titration forming complex conclusion, students conclude the results of the discoveries they made in accordance with inquiry based learning.

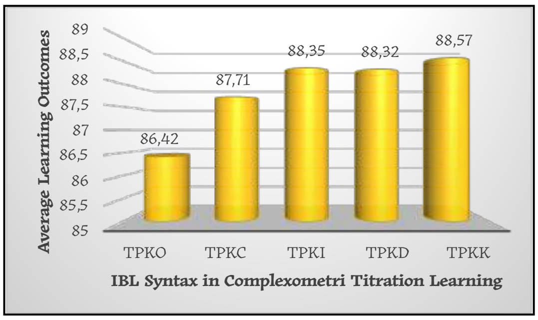

Fig.-11. Student discovery activities in complexometri titration learning

In Fig.-11 it can be seen that the discovery activities of students in determining water hardness by complexometric titration obtained the highest average value in the concluding aspect, namely 88.57, while for the investigation and discussion aspects, it was 88.35 and 88.32. The activity of doing orientation is the weakest aspect, namely the average student score of 86.42. Nonetheless, student activities in conducting analytical chemistry learning using electronic e-modules oriented to inquiry-based learning models integrated with the OBE curriculum can run well and smoothly.

Conclusion

Teaching materials for Analytical Chemistry, Gravimetry and Volumetry in the form of interactive e-modules based on inquiry based learning which are designed and developed online according to the OBE curriculum concept are in very valid criteria with an average validity value of 3.66. Inquiry-based learning-based interactive e-module teaching materials for Analytical Chemistry and Volumetry are in the criteria of being very suitable for use with a respondent achievement rate (TCR) of 92.32%. Teaching materials for Analytical Chemistry, Gravimetry and Volumetry in the form of interactive e-modules based on inquiry based learning are at high effectiveness criteria of 81.20% The value of student discovery activities in learning is classified as a good category and shows the affordability of course learning achievement standards (CPMK).

Conflict of Interests

The author (s) declares that there is no conflict of interest in this research and manuscript.

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