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The Comparison of Metacognitive Skills of Physics Education and Chemistry Education Students

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Abstract

This study aims to describe the differences in metacognitive skills of students in physics education and chemistry education in solving problems. The research subjects were students of physics education and chemistry education, Tadulako University. The research subjects were 129 people consisting of 52 physics education subjects and 77 chemistry education subjects. The research respondents who were selected were 12 people, each totaling 6 for physics education and chemistry education. Respondents were taken based on the high, medium, and low categories. The test instrument used in this study was a metacognitive skill questionnaire, and a problem solving test. According to the result of this study, it was conclude that physics education and chemistry education have different skills when problem solving.The difference in metacognitive skills of physics and chemistry education student in solving the problem is when using planning skill that are determining goals, strategizing and connecting the right concept in problem solving. However, physiscs and chemistry education students did not use metacognitive skills monitoring and evaluation properly because they tend to experience confusion so they can't solve the problems properly. This could be due to the different understanding and mastery of the material for each individual.

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Introduction

Metacognition is one aspect of cognition that has an important and effective role in the process of reflection, and directing one's thinking to problem-solving, is also one of the advantages of expertise in certain fields and knowledge skills. Experts use metacognitive strategies to complete understanding, problem-solving and make self-corrections. Therefore, an assessment must be carried out to determine whether a person has good metacognitive abilities (Newell, 1990).

The concept of metacognition was originally introduced in the context of children's learning. As a person grows older, children develop theories about what it means to learn and understand, thus greatly influencing how they put themselves in learning (Bereiter & Scardamalia, 1989). The learning process certainly does not escape the teaching process which in practice should be in accordance with the metacognition approach to learning that focuses on self-sensing, self-assessment, and reflection on what works and what needs to be improved. These practices have been shown to improve the extent to which students transfer their learning to new settings and events (Palincsar & Brown, 1984; Scardamalia, et al., 1984; Schoenfeld, 1992).

Iskandar (2014) shows that educators need to try to train students to have metacognitive skills and bring them up so that they can ultimately improve the science problem-solving skills that are the focus of science education in Indonesia. The impact of his research proved a statistically significant difference in high-level thinking skills between students who had high metacognitive skills and students who had low metacognitive skills. Each individual's metacognitive skills differ from the other according to their cognition processing abilities. If learning to use metacognitive skill stages will have a good impact on yourself so that what students do can be controlled optimally.

Mota, et al. (2019) examines the importance of developing metacognitive skills in contributing to students, especially when given problem-solving assignments. Metacognitive skills allow students to know how to coordinate when to use, and how to use them on problem-solving in academic assignments. The results showed that there was an increase in students' metacognitive skills during that time period.

Individuals with well-developed metacognitive skills can use multiple skills to think about a problem or transfer what they have learned even with new types of problems. Veenman, et al (2006) stated that metacognitive skills are built on metacognitive awareness. Metacognitive skills can be observed in the steps taken in solving a problem

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(Wilson & Clarke, 2004). In solving problems, especially science learning, students are trained to solve problems using scientific methods to find answers to a problem that is being studied.

Physics and Chemistry is a science that seeks answers to the question of what, why, and how natural phenomena are related to the composition, structure, and nature, changes, dynamics, and energetics of substances. Therefore, learning it requires skill and reasoning. Harta (2019) states that science learning should try to emphasize the active learning process to build meaningful activities and learning, one of which is practicing metacognitive skills such as solving problems. There is some material in physics and chemistry that is similar to radioactivity. This study researcher conducted a comparison of the metacognitive skills of Physics and Chemistry students in solving problems that are one of the skills needed by students in facing global challenges and metacognition activities. Garrett, et al (2006) states that metacognitive skills can be developed by practicing problem-solving strategies thus opening up opportunities for students to monitor, correct and assess their own problem-solving strategies.

The condition of the metacognitive skills of Physics Education students at Tadulako University was revealed by Rahmawaty, et al (2020) and Haeruddin, et al (2020). Research on physics education students of class 2016, 2017, and 2018 conducted by Rahmawaty, et al (2020) revealed that students' low metacognitive abilities were due to a lack of knowledge and memory of the material, making it difficult to determine strategies, planning, and skills in solving physics problems. Furthermore, the research of Haeruddin, et al (2020) developed an instrument to measure metacognition in solving physics problems. In the initial observation process, the researcher found that most of the students were only able to solve problems that were similar to the examples given. This means that students only memorize examples, but do not understand the problem-solving process nor do they include metacognitive skills.

Information about the metacognitive skill condition of Tadulako University Chemical Education students was carried out by Silmi (2019) and Ijirana & Supriadi, (2018). Silmi (2019) found that with elements of metacognitive skills, namely planning, monitoring, and evaluation, students easily understand problem solving paths. Ijirana & Supriadi (2018), whose findings reveal that students' metacognitive skills are still low in the monitoring and evaluation elements. Students are only able to solve problems in the planning section where they can translate several problems well by demonstrating their ability to identify problems.

Several other studies related to metacognitive skills in the fields of Physics and Chemistry include Abdullah (2009) on the pattern of solving physics problems from a metacognitive perspective. This study describes in detail five metacognitive skills, namely monitoring, organizing, evaluating, reflecting, and justifying which are demonstrated in various problem solving steps. Mariati (2012) also found the highest metacognitive ability on the topic of Particle Kinematics in procedural and planning components. Metacognitive skills in chemistry carried out by Sophianingtyas & Sugiarto, (2013), Ratnawati, et al (2015), and Zuniati & Sugiarto, (2015), are related to the analysis of metacognitive skills and activities of metacognitive characteristics of Chemistry students by classifying metacognitive behavior categories skills in problem-solving processes, Also another study related to problem solving by Kim, et al (2013) on the elements and patterns of students' metacognition across academic levels.

Based on the description above, it can be stated that there is no research that specifically compares the metacognitive skills of students in different science branch groups, then the researchers will study, classify and compare the metacognitive skills of physics and chemistry education students on these questions. The process of metacognitive skills is related to problem solving, because it requires cognitive knowledge, planning, evaluation and strategies in the problem solving process so that it can provide objective information about the thinking process. If metacognitive skills seem relevant in problem solving science, especially in the fields of Physics and Chemistry among students, then it seems that metacognitive skills can play a role in helping students solve problems. The selected material is about radioactivity with the consideration that the material is part of the field of Physics and Chemistry.

This article will describe the difference of metacognitive skills of physics and chemistry education students in problems solving.

Materials and Method

This research is qualitative research is descriptive. The research will be carried out in the Environment of The Physics Education Study Program and the Chemical Education Study Program of the Faculty of Teacher Training and Education, Tadulako University, Palu Central Sulawesi. The subjects of this research are physics education students of the class of 2018 and chemistry students of the class of2018 who have completed basic physics courses II and basic chemistry II. The study subjects numbered 129 people consisting of 52 physics education students and 77 students of chemistry education. The

number of respondents was as many as 12 people, namely 6 physics education students and 6 students of chemistry education. The selection of 12 research responders was given the FIS code for physics education, and KIM for chemistry education, then given the high symbol code (T), medium (S), low (R), and sequentially the respondent number from the number 1 to d 12. The instruments used in this study are:

(1) Metacognitive Activities Inventory (MCAI) questionnaire developed by Cooper and Sandi-Urena (2009). The MCAI questionnaire was given to measure the activity aspects of the study subjects' metacognitive skills. Aspects of metacognitive skills activity are measured, namely aspects of planning, monitoring, and evaluating. The MCAI questionnaire consists of 25 statements grouped into 2, namely negative statements and positive statements. The number of questionnaire statements was 8 negative statements and 17 positive statements.

(2) Test problem solving skills related to radioactivity material. The problem-solving ability test consists of 4 problems that were developed by the researcher. This instrument is used to reveal the metacognitive skill process of physics education and chemistry education students in solving radioactivity problems. Radioactivity is a material which teaches physics and chemistry. The choice of material in this instrument is also intended to reduce inequality between the respondents of the physics and chemistry research group.

Data analysis techniques conducted using data analysis according to Milles & Huberman, (1984) include:

(1) data reduction, making transcripts of data from written test results using thinking-aloud methods that contain the planning, monitoring and evaluation stages when working on problem solving problems, making transcripts of interview results, re-examining data by playing recordings of thinking-aloud results and interviews, thinking-aloud results and interviews that are not in accordance with the purpose of the study will be ignored.

(2) presentation of data, presenting written test result image data, presenting tinking-aloud transcript results table data, and presenting interview results citation data.

(3) conclusions, the results of research that has been analyzed further obtained conclusions about the comparison of metacogntive skills of physics and chemical education students.

Results and Discussion

The test results are presented in the form of answer sheets and recordings of thinking-aloud and interview recordings. Thinking-aloud activities are used to provide an open description of the behavior and metacognitive skills of research respondents when they problem-solving in the hope that the resulting data contains clear information. In order to obtain verification and clarification of data from the research respondents, semi-structured interviews were conducted. The three methods are interrelated to support the clarity of the data, because if there is a difference in the data between the results of thinking-aloud and the interview, the test data is written as another comparison.

Researchers only describe the results of the comparison of metacognitive skills of physics education and chemistry education students in the high category, namely FIS-T1, FIS-T2, KIM-T7, and KIM-T8. This is done for the purposes of this article, without reducing to the meaning and essence of the research objectives.

The Students's Palnning Skill in Problem-Solving Process

Table 1. The Student's Trancript Thinking-aloud

Physics education students	Chemistry education students
FIS-T1 [reading the problem] N it $_{14}^{7}N$ [writes = X $+_{4}^{2}\alpha$ X element, [writes the element]. I can get such a result by reducing the value of its mass [pointing to the reaction equation] i.e. Z of nitrogen is subtracted Z from alpha, then atomic number N is subtracted by alpha atomic number, $_{10}^{5}X$.	KIM-T7 [reading the problem], Oh! So, cosmic rays are alpha articles, from the firing of the nitrogen nucleus releases a proton means this one is summed up by this [referring to the nitrogen data A=14 and Z=7]. So the element is Nitrogen with a mass number and the atomic number is 7, $^{14}_{7}N$, so cosmic rays [read about] nitrogen are fired with alpha particles, thus releasing protons. So the disni it releases is a proton means its charge is minus (-) because it releases. This shooting resulted in a new core. At the time of this firing, the nitrogen nucleus binds to electrons and re-binds the new nucleus to become the N nucleus meaning there is also a plus value (+) that goes into the nitrogen nucleus. Means the reaction $N + {}^{14}_{7}N\alpha^{-} \rightarrow 2N\alpha^{+}$
IS-T2 [reading the problem] So, for this part A question, what is asked is the reaction that occurs after the firing of a nitrogen nucleus that releases a proton. From this matter it means that I know that this is alpha decay. So the answer is part a, the reaction that occurs means [writing the reaction] $^{14}_{7}N + X + {}^{4}_{2}\alpha \rightarrow {}^{1}_{1}p$	KIM-T8 [reading the problem] Here we know that Nitrogen has a mass number that is 14 and atomic number 7 [writes nitrogen information A = 14, Z = 7] then part a is in action [truncated formula] here the alpha particle is the mass number 4 and the atomic number 2, meaning approximately Boron [Writing the equation: $^{14}_{7}N\,^{14}_{7}N \rightarrow {}^{10}_{5}B + {}^{4}_{2}He$]

Based on Tabel 1, show that FIS-T1 respondents read the problem according to the instructions of the researcher. In the planning stage FIS-T1 immediately writes down the information needed in solving the problem and predicting answers. Seen from the thinking-aloud process, FIS-

T1 does not require much time from the moment after reading the question and writing down the answer. The thinking-aloud quote in the table above shows that FIS-T1 has not been able to translate the problem, and the purpose written is only 1 goal. FIS-T1 also does not understand the meaning of each sentence of the information provided. FIS-T1 applies knowledge about the value of α i.e. $^{2}_{4}\alpha$ and the strategy used by FIS-T1 is to apply the concept of equations that are the state of the right and left segments in the reaction equation must be the same, but because the initial information cannot be fully identified, so the equation written by FIS-T1 is not precise. FIS-T1 uses a sign equal to (=) on $^{7}_{14}N = X$ + and is also less $^{2}_{4}\alpha$precisely placed in solving this problem, in line with the interview excerpt and the answer below:

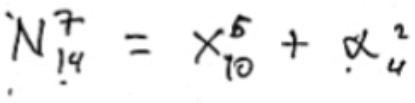


Figure 1. FIS-T1's planning results

Furthermore, FIS-T2 respondents read the problem according to instructions from researchers. FIS-T2 identifies all information in full and precisely. FIS-T2 uses the knowledge it has to connect concepts into the problem-solving process, outlined as follows.

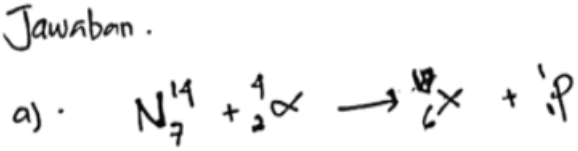


Figure 2. FIS-T2's planning results

Based on figure 2 above it is clear that FIS-T2 wriote down all the data provided by the problem, namely, $^{14}_{7}N$, and, so that $^{4}_{2}\alpha + ^{1}_{1}\mathrm{p}$. Based on thinking-aloud, FIS-T2 also able to identify the purpose of the problem i.e. reaction equations and newly formed nuclei. FIS-T2 said "*[...]This means that I know that this is alpha decay*" pointing out that FIS-T2 can plan concepts that fit the problem, then use that understanding and experience into problem solving.

KIM-T7 is unable to capture information well, and did not understand the intent of the matter. There's the following interview.

[Researchers]:
why the results of the reaction that there is written 2N a +?
[KIM-T7]:
I think that nitrogen in the air has 2p frame bonds that are diatomic. But in the question information it is not said that nitrogen is diatomic so I want to make my own answer with the diatomic theory. Then there is the release of alpha, definitely marked with min (-) and produces a new nucleus so I fill in the plus sign (+)

That statement indicates that KIM-T7 related the memory or preliminary knowledge to nitrogen elements that have diatomic properties to solve this problem. Researchers also got the fact that respondents seemed confident with the answer.

Kim-T8 wrote information about nitrogen and alpha particles. Respondents could not find information at the end of the sentence, namely information about protons. Then the respondent immediately said that the result was roughly Boron.

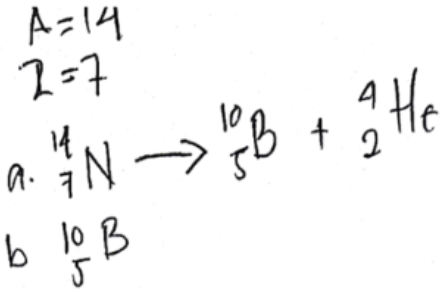


Figure 3. KIM-T7's Planning Results

Based on figure 3, respondents did not take long to solve the problem. KIM-T8 spontaneously stated that the result of the equation was Boron. Thinking-aloud process show that the self-confidence of KIM-T8 when solving problems.

After the interview, it turned out that respondents could remember the periodic table of elements that coincidentally connected with the results of the respondent's quick count process.

[KIM-T8]: so after I observe the equation this reaction can be solved using the law of conservation of mass numbers and atomic numbers. So from the reaction produces 10B5 because in the periodic system the element that has the atomic number 5 is boron.

Kim-T8 explained that to solve this problem is the law of conservation of mass numbers and atomic numbers and enough knowledge of the periodic table of elements.

The Students's Monitoring Skill in Problem-Solving Process

Table 2. The Student's Trancript Thinking-aloud

Physics education students	Chemistry education students

FIS-T1 [wrote $_{14}^{7}N = X + {}_{4}^{2}\alpha$] [wrote elements] $_{10}^{5}X$	KIM-T7 Wrote : $^{14}_{7}N = N + \alpha^{-} \rightarrow 2N\alpha^{+}$
FIS-T2 [wrote the equation] $^{14}_{7}N + {}^{4}_{2}\alpha \rightarrow X + {}^{1}_{1}p$, means [muttering] this is reduced or added huh [?] [with a small volume of sound], I forgot for his mass number to be reduced or added [muttering], [doing calculations by shrinking the volume of sound] [writing the results of the calculation on element X]] $^{14}_{7}N + {}^{4}_{2}\alpha \rightarrow {}^{10}_{6}X + {}^{1}_{1}p$. Alfa that the mass number was reduced to 4, then the atomic number was reduced by 1.	KIM-T8 Wrote : $^{14}_{7}N \rightarrow {}^{10}_{5}B + {}^{4}_{2}He$

Based on table 2, FIS-T1 explained the first steps you need to take to solve the problem. FIS-T1 uses the strategies to solved problems and tried to use the solution step correctly. FIS-T1 performs a mathematical procedure that is seen in the answer sheet pieces and thinking-aloud process below.

[FIS-T1]:
[wrote the answer] ZN - Za, AN – Aa
[entered the value] ZN - Z = 7-2 = 5,a AN - A = 14 - 4 = 10.

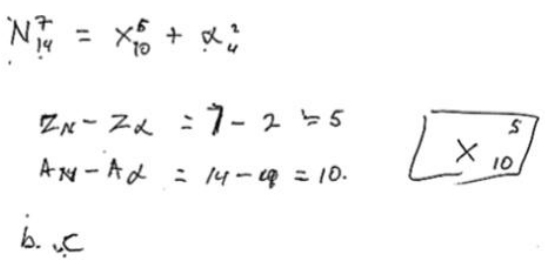


Figure 4. FIS-T1's Monitoring Results

Based on figure 4, showing that the stages of mathematical procedure are good, it's just wrong to include values in the symbols of atomic number (A) and mass number (Z). FIS-T1 also continues to strive to get the right results in solving existing problems, but FIS-T1 is confused to find what elements have atomic number 5. FIS-T1 did not monitor this troubleshooting process because when there is confusion, FIS-T1 does not double-check questions and answers so it does not realize that there is something wrong in the problem-solving process. It can be interpreted that FIS-T1 is less than optimal in the aspect of monitoring, although ideally at the planning stage it is also necessary to monitor and recheck to achieve the expected results.

FIS-T2 has not been optimal in conducting monitoring stages. This is indicated by doubts at the final settlement. FIS-T2 looks hesitant when applying strategies about the law of conservation of mass numbers and atomic numbers into mathematical procedures, so that there is a fallacy in solving the problem.

There were doubts seen in the FIS-T2 statement when it started muttering, shrinking the volume of the sound, speaking like stammering. FIS-T2 cannot find the right concept to solve the problem that in the reaction equation the number of atomic numbers and mass numbers is the same in both segments of the reaction. Although the final answer turned out to be wrong, FIS-T2 realized that there was something wrong with the understanding of the concept this was clearly seen during the following interview session.

[Researcher]:
Look at the answer sheet, you write the following reaction results: $^{4}_{2}\alpha + {}^{14}_{7}N \rightarrow {}^{11}_{6}X + {}^{1}_{1}p$*, How do you get an answer like that?*
*[*FIS-T2*] :*
After I worked and realized that there was a mistake, my understanding that in alpha decay was the mass number was reduced by 4 and the atomic number was reduced by 2, kemudian equally added with the value of 1 proton, so that the result $^{11}_{6}X$
[Researcher]:
The purpose of part b means you can't finish?
*[*FIS-T2*]:*
Yes, because it was wrong in part a, automatically I could not finish on part b.

Through the researchers' observations of FIS-T2, this confusion led to the non-optimal FIS-T2 skills in the monitoring aspect. Because applying the wrong strategy, it has an impact on the mathematical procedures used is also not appropriate.

KIM-T7 performs the confidence judgment monitoring stage skill that is confidence in self-consideration by analyzing the problem only pieces, causing difficulties in evaluating the work. Interestingly, at the end of the statement, KIM-T7 said *"[...] to be honest I just count the release of an electron. Since I always thought that the nucleus in the middle was neutral, it had no charge unless the electrons were moving. Maybe there could be a transfer of electrons. So, I can't do this"*. This, statements contrasts with the process at the beginning of problem solving where respondents look confident. Apparently, there are several ways repondents overcome dificulties in problem solving one of which is by "giving up".

Kim-T8 said "[...] *my answer is obtained from the firing of alpha particles [pointing to the answer], where it is known that the element nitrogen is atomic number 7, and alpha has atomic number 2, I add boron element i.e. atomic number 5*. If the respondents had done the monitoring process in the initial planning, and monitoring with the right initial strategy and knowledge then this problem might be solved

The Students's Evaluation Skill in Problem-Solving Process

Table 3. The Student's Trancript Thinking-aloud

Physics education students	Chemistry education students
FIS-T1 Evaluation: So element, [muttering] means element atomic number 5, [...] element carbon 6, then what's the answer huh [?](_10^5)X [...] I don't know what element has an atomic number of 5.	KIM-T7 Evaluation: Nitrogen is diatomic hence the result is 2N+,αso we just calculate the new core. This released nucleus, produces a new core. So, the new core is what, honestly I never get the core calculation, usually I just count the release of the eketron. Because I always thought that the nucleus was neutral, it had no charge unless the electrons were moving around. Maybe there could be a transfer of electrons. So I can't work on this. The result I obtained was 2N+,α2 this was obtained from the nature of nitrogen. Nitrogen is in the Earth's atmosphere, is always diatomic, has a double bond and has 2 hands, so the result is $2N\alpha^{+}$ KIM-T8 Evaluation: That's roughly the result of Boron. [...] My answer is obtained from the firing of alpha particles [pointing to the answer], where it is known that the element nitrogen atomic number is 7, and alpha has atomic number 2 i.e. helium [pointing to answer $^{4}_{2}He\,^{14}_{7}N \rightarrow\, ^{10}_{5}B+\ ^{4}_{2}He$] how much add how much produces 7 i.e. I add the element Boron which is atomic number 5

Based on table 4, the final answer obtained by FIS-T1 is to know the formed after the shooting of alpha particls but in thinking-aloud, FIS-T1 said that *[...] I don't know what element has atomic number 5. Therefore, FIS-T1 only writes the symbol X for the element without knowing the name of the* $^{5}_{10}X$ *element.*

FIS-T2 has not yet received results in line with expectations. FIS-T2 also looks rushed to decide the final answer. FIS-T2 doesn't seem to want to spend a lot of time remembering things that might be able to connect concepts in solving this problem like the transkip below.

[Researcher]:
Did you usually double-check your answers?
[FIS-T2]:
Yes, I was the type of person who definitely check back whether my answer makes sense or not when I finish working on the problem.
[Researcher]:
Did you evauate this problem?
[FIS-T2]:
Yes. I did, after I worked I thought it seemed like my answer was wrong but I had no other way to finish it

Thus, FIS-T2 has not met the metacognitive indicator in the evaluation stage.

Kim-T7 and KIM-T8 respondents did not get the right solution to solve the problem.

Based on the results of the research that has been described above shows that there are differences in the metacognitive skills of physics and chemical education students in solving problems. First, there is a difference in metacognitive skills in the planning aspect. The difference in planning in question is the difference in obtaining something useful from the data, the difference in determining the relationship between the data and the questioned, the difference in obtaining a completion plan and connecting with a concept.

In the aspect of planning, physics education students and chemistry education students tend not to obtain complete data by ignoring information related to proton release. This says that students cannot process information from the results of the problem reading given. Comparable to research conducted by Sundari & Rimadani (2020) students have not been able to manage information properly and completely from a data. This is because students did not read the problem carefully, so students cannot determine what are useful information to be able to solve problems. In line with Yudiani, et al (2014) who stated that reading is essentially an activity that seeks to interpret connecting information and finding answers to cognitive questions from problems faced in the form of story problems. Then it relates to the theory developed by Flavell (1979) that retrocognition has an important role in understanding reading when reading the problems.

Furthermore, the difference in terms of linking the concept with the settlement plan. There are physics education students who use the concept of alpha, beta, and gamma rays simultaneously, some apply the concept of reducing the atomic number and mass number on the left and right segments while chemistry education students there who apply the concept of nitrogen in the earth's atmosphere are always diatomic, some even use the concept of electron configuration. The concept applied by this student is not in accordance with what is expected to solve the problem. This is in line with the results of research from Gok (2014) stated that problem-solving strategies have a positive effect on problem-solving skills on aspects of understanding problems and planning solutions. In addition, the solution strategy affects the final outcome or purpose of the problem.

Differences in planning skills are also seen from the way of writing reaction equations where physics education students write reactions using the sign (=) while chemistry education students write reactions with signs (→). Then, there is the difference in how to give symbols to alpha particles and elements formed from the firing of nitrogen by alpha particles. Physics education students tend to give symbols ($^4_2\alpha$) for alpha particles and X symbols for the elements formed while chemistry education students give symbols (^4_2He) and do not give symbols X but instead directly predict and write the symbol of the element in question.

On the skills of monitoring the completion steps carried out by physics education students and chemistry education students, on average, there was confusion. These confusions lead to suboptimal monitoring skills. This is comparable to research by Dowd, et al (2015) which found that when relevant factors cannot be controlled, one may not be able to separate and identify the positive aspects of the confusion and this affects metacognitive skills.

On the evaluation skills, the behavior shown by students of physics education and chemistry education is not recognizing the existence of errors in solving problems so as not to make improvements to errors. This is not in line with Apriyanti, (2016) that the aspect of refinement in metacognitive skills is the evaluation aspect. Aspect evaluation is an analysis of the overall performance results and effectiveness of strategies in solving problems.

Conclusion

Based on the results of the study concluded that physics education and chemistry education have different skills in problem-solving. The difference in metacognitive skills of physics and chemistry education students in solving problems is when they use planning skills, namely in determining goals, developing strategies, and connecting the right concepts in solving problems. However, students of physics and chemistry education do not use monitoring and evaluation of metacognitive skills well because they tend to experience confusion so that they cannot solve problems properly.

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