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Pre-Service Chemistry Teacher's Conception About Chemistry of The Rare Earth Elements

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ABSTRACT

Rare Earth Elements (REE) is an interesting chemistry topic, especially due to current technology development. However, new learning designs of REE need to be developed for Pre-service Chemistry Teachers (PCT) as it is not yet available. A good design is constructed by analyzing PCT pre-conceptions based on the technical difficulties faced by the students during teaching process. The study aims to identify PCT's pre-conceptions focusing on REE topic. We conducted this research involving 17 chemistry education students at the Universitas Pendidikan Indonesia, Bandung. Data was collected through interviews and analyzed using the Qualitative Content Analysis (QCA) method. Our results highlight that PCT had difficulties with chemistry content of REE, especially about electronic configuration, magnetic, and luminescence properties. In addition, PCT faced difficulties correlating electronic configuration's chemistry content into contexts. Based on the interview results, 88.2% of the students agree with the development learning design for undergraduate chemistry students. As a result, we conclude that technical difficulties and misconceptions about REE can be overcome by developing the learning design based on the need of the students.

Keywords: conception, inorganic chemistry, pre-service chemistry teacher (PCT), rare earth elements

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1. Introduction

The Chemistry Education Study Program aims to educate chemistry teachers to have a good professional knowledge that includes Pedagogic Content Knowledge (PCK) and Content Knowledge (CK). CK is defined as the body of knowledge and information that are learned by the students in a particular subject or content area (Tal et al., 2021) and it is necessary for PCK (Hermanns, 2021). In chemistry education, CK enables students to understand matter and its organization (Lewis et al., 2021). CK that needs to be mastered by students refers to facts, laws, principles, and theories in chemistry. Chemistry is considered as a complex subject by both students and teachers. The complexity of chemistry learning is caused by several factors, such as abstract nature of chemistry, many chemical concepts, and the difficulty of using chemical symbols (Pinarbasi & Canpolat, 2003). Based on Louis, Pratomo and Sugiyarto's (2014) research, chemistry teachers also experience difficulties and still need to improve their basic chemistry knowledge specifically in inorganic, organic, and physical chemistry (Supiah et al., 2017). The research beforehand illustrates the weakness problem of chemistry teachers in mastering the core subjects in chemistry. Therefore, the Pre-service Chemistry Teacher (PCT) needs to strengthen their knowledge of chemistry, especially inorganic chemistry.

Inorganic chemistry focuses on the classification and explanation of elements in the periodic table, the main inorganic substances and reactions, fundamental theories (such as the theory of electronic arrangement) and some principles of characterization techniques (Xiao et al., 2020). Inorganic chemistry course is abstract. The fact that it is abstract, most of the students learn the topic by memorizing them. Thus it is challenging to build essential concepts (Adesoji & Omilani, 2012; Suyanti et al., 2006). On the other hand, learning about elements is crucial aspect in inorganic chemistry, but it becomes monotonous if the students only learn it by recalling memories. Context-based teaching and learning could be an alternative solution for teaching strategy. The context-based strategy useful to encourage the students about relevant situation which help them interpret the natural world, encourage more positive behavior and improve the abillity to understand chemistry (Franco-Mariscal, 2018).

Rare Earth Elements (REE) is one of the topics in the chemical element discussion. REEs are Scandium, Yttrium, and others elements in Lanthanide groups (Jha, 2014). REE was discovered in the 18th century, and its applications have been widely used for many industries such as semiconductor, battery, solar panel. Scientific interest in REEs has been significantly increased due to their properties for some applications (Kang & Kang, 2020). REE is critical to the technologies in communications, transportation, medicine, energy, surveillance, and military applications (Klinger, 2018). The use of REE covers multi-sectors and disciplines. From geopolitical point a view, REE results in a complex discussion spanning from its' scarcity, mining production hazard, environmental damage and sustainability (Klinger, 2018; Voncken, 2016). Therefore, the discussions about REE are diverse and can be used to enrich the context learning. Context learning is useful to help the student overcome problems regarding abstract nature of chemistry and its irrelevant to daily life.

According to the Committee on Professional Training, REE topic is not part of the inorganic curriculum. The conceptual topics cover atomic structures, covalent molecular substances, main group elements, transition elements, coordination chemistry, organometallic chemistry, solid-state materials, and special topics (American Chemical Society, 2008). Several topics can be developed in chemistry education curriculum, such as REE which indifferent with main group element. In terms of content, REE topic also discussed about abundance, properties, and their uses. Researchers see this gap as a prospect for developing learning designs about REE. We suggest the learning design can be added to the chemistry education curriculum or just as an additional course.

Niebert and Gropengiesser's (2013) study explains that analyzing student's prior knowledge and scientific conception has been proven to help create a good learning design. Pre-conception (initial concept or prior knowledge) is the basic concept that students already have before the learning process begins (Suma et al., 2019). Initial conception, pre-conception, or prior knowledge are terms that have identical meanings. In this study, the term pre-conception will be used. This pre-conception is important as a basis for building student next knowledge (Redhana et al., 2017). According to the constructivism theory, students build new knowledge based on previous learning by reconstructing previous knowledge (Jain et al., 2013; Suma et al., 2019). One of the importance of reviewing students' pre-conceptions is to know learning difficulties and misconceptions faced by the students. Misconceptions arise when the student's conceptions do not match the scientific conceptions. It is difficult to eliminate misconceptions that occur in students (Saputra et al., 2019). Through prior observation of students' pre-conceptions, misconceptions can be avoided from the learning that will be designed. In this case, misconceptions are not only interpreted as learning difficulties. However, misconceptions can be used as refinement in the learning process as a part of conceptual change (Lewis et al., 2021).

Based on the aforementioned motivation, learning design with REE topic is crucial to be developed. This study aims to identify the pre-conception of PCT in terms of REE chemistry content and context. The study also obtained an initial opinion from PCT about the importance of developing a learning design related to REE. The results of this study could be used as basis to develop REE learning design and teaching material.

2. Research Method

The main aim of this study is to identify the pre-conceptions of PCT related to the REE topic. This study involved students from Chemistry Education at Universitas Pendidikan Indonesia, Bandung as the participant. The sampling technique was purposive sampling, where the researchers' select respondents who fit the criteria to participate. The participants in this study consists of 12 post-graduate and 5 under-graduate students. All participants are taking the even semester of 2020/2021 and have passed the inorganic chemistry course.

The instrument used was a semi-structured interview. Semi-structured interviews combine structured and unstructured interviews to gather systematic information about the main topic allowing exploration if additional information emerges during the interview (Wilson, 2014). Data collection through interview have the advantage such as gaining in depth information (Gurel et al., 2015). The author prepared a questionnaire consisted of 20 questions divided into three categories. The first category addresses the topic related to chemistry content, context, and their relationship to REE. The second category contains several questions about the importance of studying REE in chemistry learning. The third category contains ~~asked~~ questions about the urgency of learning design related to REE. Due to the current situation of the COVID-19 pandemic, the interview technique was conducted through the online meeting as shown in Figure 1. The interview was conducted for 30-40 minutes for each respondent. The interview results then translated into transcript.

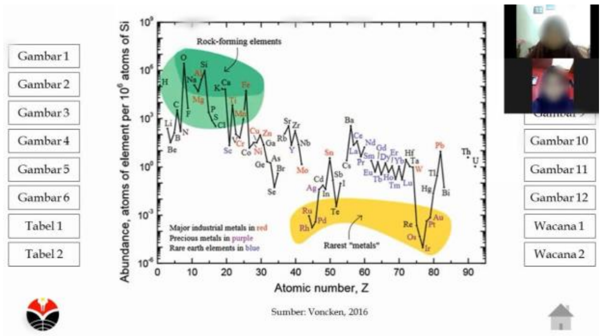


Figure 1. Student Interviewed Via Zoom Meeting

The interview transcripts were analyzed using the Qualitative Content Analysis (QCA) method (Mayring, 2015). The qualitative content analysis identifies and categorizes similarities in student's answers during interviews by finding patterns that characterize respondent's ideas. The stages of data analysis were carried out as follows: editing the text on the transcript to improve readability, interpreting statements on the underlying conception, and formulating answers into categories (Niebert & Gropengiesser, 2013). Answers are categorized and given a score of 0, 1 and 2. A 0 is given if the students do not know or answer incorrectly or deviate from the concept that being asked. 1 is given if the answers of have misconceptions or partially correct. 2 is given if the students know the concept and provide answers according to the scientist's conception. All author participated in content analysis to ensured students' answer are sorted into the correct categories. The triangulation method was used to ensure that the research far from subjectivity. Data analysis results were presented using descriptive statistics through percentages and a chart bar.

3. Result and Discussion

The questionnaire contains 20 questions asked to explore the pre-conception of PCT. However, in the first question, students only asked whether they had ever studied REE. 11.8% of students have studied REE. Furthermore, after questioned again the students had studied REE from a workshop held by the university. 23.5% have heard and read about REE but not in-depth. These students only hear and look at REE in the periodic table, but they never learn about REE. 64.7% of students have never studied REE. All students in this study have taken inorganic chemistry courses, but many have never studied REE. It is because the REE topic is not given in the curriculum. Then in the first category, students were asked 16 questions regarding knowledge about chemistry content, context, and the relationship to REE, as shown in Table 1.

This questionnaire is developed based on analysis of six pieces of literature consisted of two books, two monographs, a review article, and a research article. The literature study shows the essential learning material related to REE consisted of definition, electronic configuration, properties, especially in magnetic and luminescent properties, abundance, production process, application, and REE recycle issue. The preliminary analysis result is used to find the scientific conception which practically used as a correct answer for each question.

Table 1. Asked Aspect in Interview Question

Question No	Aspect (Chemistry Content/Context/The Relationship)
Q1	Content: REE's definition
Q2	Content: Electronic configuration
Q3	Content: REEs electronic configuration
Q4	Content: REEs magnetic properties
Q5	Content: REEs magnetic properties
Q6	Relation between magnetic properties and context of REEs in everyday life
Q7	Content: Luminescence properties
Q8	Content: REEs luminescence properties
Q9	Relation between luminescence properties and context of REEs in everyday life
Q10	Content: Lanthanide contraction
Q11	Content: REEs mineral
Q12	Relation between electronic configuration, properties and REEs mineral
Q13	Relation between lanthanide contraction, REEs mineral and production processes
Q14	Relation between REEs production process and environmental aspects
Q15	Context: Electronic Waste (E-Waste)
Q16	Context: E-Waste Recycling

3.1. Student Pre-conception About Chemistry Content, Context and The Relationship Related to REE

The first question (Q1) in this category is REE definition. Students were asked to define the REE by relating them to a graph contained about chemical elements abundance in earth. 23.5% of students cannot read the information available on the abundance of elements graph, and these students fail to relate the abundance with the REE definition. 58.8% of students experienced misconceptions related to the defining REE. These students define REE without relating to abundance of elements graph. They define REE as "rare" because it is hard to process, so these elements are hard to find on the earth. Other students agree that REE is "rare." These students not relate REE definition to REE abundance in the graph, but relating to the abundance of main group elements. It is caused by main group elements more familiar to the students rather than REE. Therefore, this student's conception is different from scientific conception. Only 17.6% of students were able to explain the definition of REE according to the scientist's conception. According to scientists' conceptions, REEs are not as "rare" as their name implies. The number of REE deposits is limited, but the elemental abundance is quite large. From the abundance of elements graph, the most common REE is cerium (Ce). It is the 27th most abundant element on earth with approximately 60 ppm in earth crust. Cerium has more abundance than Lead (Pb) which only consisted 10 ppm. The rarest REE, lutetium (Lu), has an earth crust abundance of 200 times greater than gold (Au) (Atwood, 2012; Castor & Hedrick, 2006; Voncken, 2016).

All of the students had studied electronic configuration. In Q2, students were asked to explain how to write the electronic configuration of an element in general. 41.2% of students were able to write the electronic configuration correctly. These students can explain two ways of writing electronic configuration, based on shells (Bohr Theory) and subshells. 58.8% of students cannot explain how to write the electronic configuration completely. These students only mentioned the electronic configuration as filling electrons in the 1s, 2s subshells.

In Q3, students were asked to write down the electronic configuration for Gadolinium, with atomic number 64. The result, 29,4% students were mistaken in writing the configuration. The error occurred due to the student's inaccuracy in filling the electrons in the 4f orbital. 41.2% of students experienced misconceptions in writing the electronic configuration of REE. The student's misconception answer can be seen in Figure 2. Students write the electronic configuration for gadolinium as [Xe] $6s^2 4f^8$ according to Madelung rules and Mnemonic diagrams. The correct electronic configuration for the element gadolinium is [Xe] $6s^2 4f^7 5d^1$. In general, the electronic configuration in the ground state is determined by the principal quantum number (n) and the angular momentum quantum number (l), and the order in which the orbitals are filled *is* determined by a rule ($n+l$) known as the Madelung rule (Huang, 2010; Voncken, 2016). However, gadolinium is one of REE with an electronic configuration that does not follow a simple orbital filling order (Miessler & Tarr, 2013). Gadolinium has an electronic configuration of [Xe] $6s^2 4f^7 5d^1$ instead of [Xe] $6s^2 4f^8$. This phenomenon exists due to the stability of the half-filled subshell. Only 29.4% of students could write the electronic configuration of gadolinium correctly. However, after further questioning, the students could not relate their answer to electronic stability correctly.

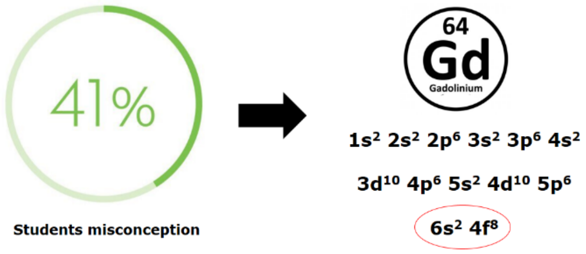


Figure 2. Student's Answer with Misconception in Writing The Electronic Configuration of Gadolinium

Q4 is related to REE magnetic properties. 52.9% of students explain that many REEs have paramagnetic properties, and only gadolinium has ferromagnetic properties. 41.2% of students only know that REE has paramagnetic properties, while 5.9% do not understand the unique properties of REE. In the following question Q5, students were asked the cause of the magnetic properties in REE. 47.1% of students do not know the cause of REE having good magnetic properties. These students relate the presence of the magnetic properties of REE to the temperature, metallic properties, atomic number, and electrons scattered in the s, d, and f subshells. 29.4% of students experienced misconception about magnetic properties. These students assuming that the magnetic properties of elements are related to the spin quantum number but assume that the paired electrons cause these properties. 23.5% of students can explain the relationship between magnetic properties influenced by spin and unpaired electrons. However, the magnetic properties of REE are different from transition metals because the magnetic properties are dominated mainly by spin, orbital angular momentum, and electron interactions (Atwood, 2012). The next question Q6 is related to the relationship between the magnetic properties of REE with the context of everyday life. Students were asked about the function of REE in microwave devices. None of the respondents could correctly explain the function of REE in the microwave. 35.3% of students know that there are REE in the form of magnets in microwave components but do not know the function of these elements. Another 64.7% of students were not able to relate the magnetic properties of REE to their application in the microwave.

In the Q7, students were asked to distinguish between the two photoluminescence phenomena. It is fluorescence and phosphorescence. Based on the results of the interviews, none of the students answered the question correctly. 23.5% of students can explain the photoluminescence process caused by atomic excitation and emission processes but do not know the difference between fluorescence and phosphorescence. 76.5% of students gave wrong answers. The students who gave wrong answer assumed that there are two different elements that involved in the phenomenon. Fluorine (F) involved in the fluorescence while phosphorus (P) in phosphorescence.

The Q8 is about the REE luminescence properties and their electronic configurations. None of the students knows that REE have luminescence properties. The luminescence properties in REE caused by the unfilled 4f subshells, consequently different arrangements of the 4f electrons can produce different energy levels. The 4f electron transition between various energy levels produces many absorptions and emission spectra (Huang, 2010). 47.1% of students know the luminescence properties of REE due to their electronic configuration but cannot explain the correlation between them. Meanwhile, 52.9% of other students did not know or gave wrong answers.

The next question Q9 is about the relationship between the luminescent properties and context in daily life. Students were asked the reason why fluorescent lamp can produce light. 5.9% of students answered correctly and explain that REE work as phosphor coating in the fluorescent lamp. Meanwhile, 17.6% of students also know that there is REE in fluorescent lamp. But, do not know function of REE in the lamp.

All students have never heard of the term "lanthanide contraction" in Q10. Then students were given help in the form of images that described the lanthanide contraction phenomenon. 11.8% of students could explain the lanthanide contraction, same as scientific conception. Lanthanide contraction means decreasing atomic and ionic radius with increasing atomic number in the lanthanide group (from lanthanum to lutetium) (Huang, 2010; Voncken, 2016). While 41.2% of students could only mention the decrease in ionic radius. The other 47.1% of students did not answer or gave the wrong answer. There are three examples of incorrect answer. One of these students mistakenly describe lanthanide contraction as converting the oxidation number from 0 (atomic condition) to +3. While other students misinterpreted radius as radiation. Some students answered that higher the atomic number easier to radiate in ions than atomic form.

Question Q11 is regarding the content of rare earth minerals. 82.4% of students were able to correctly mentioned three REEs contained in monazite minerals, Cerium (Ce), Lanthanum (La), and Neodymium (Nd). However, some students confused that Thorium (Th) is part of REE. 11.8% of respondents could only name 1 or 2 REEs contained in monazite minerals. From the answer above, students still not familiar with the 17 elements of REE. Moreover, 5.9% of students answered wrong because they did not mention elements and mentioned rare-earth phosphate compounds in monazite minerals. They were not been able to distinguish between elements and compounds.

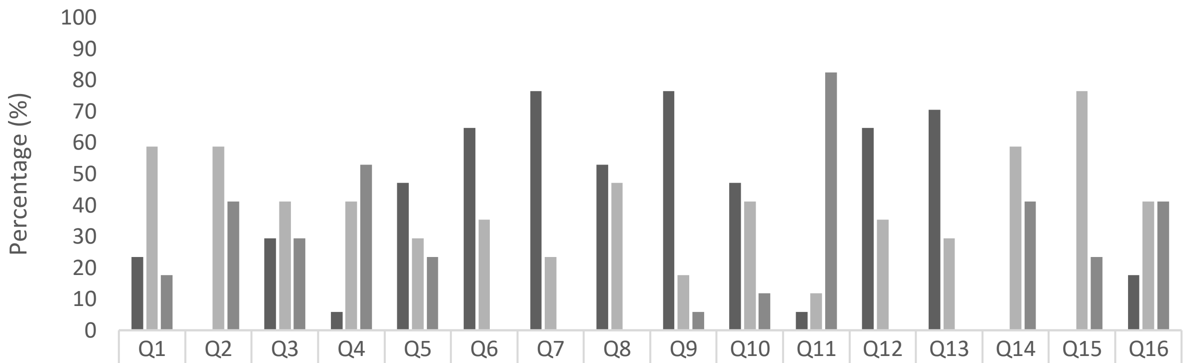
Q12 continued from Q11. The students asked to explain why the monazite mineral contain more than one REE. The students who understand the relationship between REE mineral, electronic configuration, and REE properties could answer this question. From the results of the interviews, none of the students could explain the relationship between content of mineral, electronic configuration and properties. 35.3% of students know that there is a relationship between minerals and REE properties but cannot further explain the form of the correlation. 64.7% of students do not know a correlation between minerals with electronic configurations and REE properties. The students gave the wrong answer associated REE minerals with the abundance and formation of rare earth coordination complex instead of their properties.

The next question Q13 concerns about the relationship between mineral content, production processes, and lanthanide contraction. In this question, students were asked to explain the principle of separating REE from a mineral. From the results of the interviews, none of the students could relate the answers to the three contents. However, after being given instructions regarding its relation to lanthanide contraction. 29.4% of students could mention the separation techniques used for REE production, such as ion exchange, reduction/oxidation, and extraction using appropriate solvents, but the students could not explain the correlation with the lanthanide contraction. While 70.6% of students still did not know the principle used to separate REE from minerals. The process of separating REE can take advantage of the difference due to the decrease in the ionic radius from lanthanum to lutetium (lanthanide contraction). Differences in basicity cause several effects, such as differences in salt solubility, hydrolysis of ions, and formation of complex compounds. This difference is the basis of the separation procedures that can be carried out by fractional crystallization, fractional precipitation, ion exchange, and solvent extraction methods. In addition, some REEs can form divalent or tetravalent states and allow metal separation using selective oxidation or selective reduction methods (Voncken, 2016).

In the Q14, students were asked about the relationship between the production process and environmental aspects. The production process can cause severe damage to the environment. In this question, all students already know that the production process harms the environment. The students were asked to mention the environmental damage. 41.2% of students could mention various environmental damages that occurred due to the production process and mining of REE, such as air, soil, and water pollution, contamination due to waste, damage to ecosystems both land and water, and disturb animal habitats. However, the other 58.8% of students could only mention one or two environmental damages caused by the production process of REE, such as soil pollution and air pollution only.

The last question Q15 and Q16 are related to the context of e-waste recycling. In the Q15, students were presented with a discourse about electronic waste (e-waste). Then students were ~~are~~ asked to provide any information obtained from the discourse. 23.5% of students can provide some information from the given discourse. The discourse provides annual information about e-waste in Indonesia. The pieces of information were given, such as the production of e-waste in Indonesia increases every year. E-waste still has economic value. Precious metals can be found in e-waste. Java Island contributes more than half of the e-waste produced in Indonesia. Moreover, there is no solution to overcome the e-waste problem. In comparison, 76.5% of students can only provide one or two pieces of information contained in the discourse. These students did not explore more information in the discourse.

The following question, Q16 were asked to students how to find the solutions for e-waste problem. 41.2% of students answered that they would recycle e-waste considering that there are still valuable metals in the e-waste. Another 41.2% of students also answered that they would recycle but could not consider why recycling e-waste is necessary. Meanwhile 17.6% students were not suggesting e-waste recycling. These students give irrelevant answer with recycling context such as selling, donating, or limiting the use of electronic goods for public.



	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16
Score 0	23,5	0	29,4	5,9	47,1	64,7	76,5	52,9	76,5	47,1	5,9	64,7	70,6	0	0	17,6
Score 1	58,8	58,8	41,2	41,2	29,4	35,3	23,5	47,1	17,6	41,2	11,8	35,3	29,4	58,8	76,5	41,2
Score 2	17,6	41,2	29,4	52,9	23,5	0	0	0	5,9	11,8	82,4	0	0	41,2	23,5	41,2

Figure 3. Percentage of Student Answers

The 16 questions were asked in this category, seven about chemistry content, two about context, and seven about the relationship between content and context related to REE. Figure 3 illustrates the student's answers from the interviews. The results show that PCT have learning difficulties, especially in understanding chemistry content and connecting chemistry content to context. The learning difficulties occurred in understanding REE chemistry content may arise from the abstract nature of chemistry. The concept that widely involved in REE topic is about electronic configuration that difficult to understand. Consequently, the students do not understand the concept of electronic configuration correctly that has been taught in the learning. The risk may arise from student misunderstood that will lead misconception for the following content. There are several misconception about electronic configuration in students caused by insufficient knowledge about quantum theory and electronic transitions (Anwar et al., 2012). The discussion of electronic transitions is essential in REE topic because of the relation to the properties of elements such as luminescence. As shown in Figure 3, the highest percentage of students who answers did not know or gave answers incorrectly was in the REE properties, both magnetic and luminescent properties. If we look at the section on the relationship between chemistry content and context, the learning difficulty for students is related to electronic configuration, as shown in Q12 and Q13. In this section, none of students answer the question correctly. As shown from the result, it is necessary to prepare further discussion about the electronic configuration for the PCT in order to understand the REE topic comprehensively.

To overcome students' difficulties in finding the correlation between chemistry content and context related to REE. It is better to learn to be accustomed by using contextual-based learning, the students will be more motivated to learn. The students will find that their learning becomes meaningful than studying the chemistry of elements by rote learning. In this topic, students initially found that REE is rare, but after introduced with several context of REE such as in fluorescence lamp and microwave. Students more familiar that many applications of REE can be found in daily life. However, it must be recognized that the selection of context must be right that it will not cause misconception. Finally, the learning difficulties in the results of this pre-conception analysis need to be addressed in the form of learning designs that need to be developed for the REE topic.

3.2. The Importance of Studying REE in Learning Chemistry

This category contains questions asked about the importance of studying the topic of REE in learning chemistry. This category only contains two questions. The first question asked regarding how much chemistry content that students should learn related to the REE. 47.1% of students were able to mention the chemistry contents that need to be studied to understand the REE topic thoroughly. The content includes electronic configuration, properties of elements, formation of complex compounds, and chemical separation techniques. 29.4% of students only mention one or two right contents related to REE topic. Meanwhile, 23.5% of students wrongly mentioned the content. According to the students answer, studying REE required an understanding of organic chemistry. The answer is wrong because REE not belong to organic chemistry, but inorganic chemistry.

The second question asked about the benefits of studying REE in learning chemistry. 23.5% of students were able to give positive answers related to the benefits of studying REE, such as knowing the application of REE, increasing knowledge about chemistry content, and knowing the relationship between chemistry content and its application in daily life. 76.5% of students only provide 1 or 2 benefits in studying REE. No respondents did not know the benefits of studying REE, the following statement are some of the answers given by students:

"*By studying REE, it turns out that these REEs have many benefits. We can also prevent the production of e-waste because we can recycle it, and it is more environmentally friendly. Also, we know that REE have many applications in life.*" (Student 3)

"*The benefits are to know and increase knowledge about chemistry in everyday life, as well as increase knowledge about the use of REE itself.*" (Student 8)

"*I just found out that REE consist of several elements and they have many benefits, including in the industrial field, so in my opinion this topic is good to study.*" (Student 11)

3.3. The Urgency of Learning Design Regarding the REE Topic

This last category contains 1 question that explores student opinions regarding the urgency of design learning to PCT about REE. All students gave positive feedback. From the results of the interviews, 11.8% of students were still hesitant but still considered that this topic is important to learn for PCT. 88.2% of students strongly agree that REE topic should be given to PCT. The students commented that REE rarely discussed nor taught in learning chemistry. Some students expressed that REE topic is interesting and has many applications in daily life. They also recommended this topic to be taught as additional course for PCT.

REE topic has a significant urgency to be taught to PCT students which need learning design. During the interviews, students stated that this topic was important to teach in the curriculum for undergraduate Chemistry Education student. Teaching this topic will be very useful for PCT. Especially for PCT that majority will teach in high school. In the high school curriculum, the REE topic includes the periodic system of elements for grade 10 and elemental chemistry for grade 12. In high school, learning elemental chemistry for grade 12 is considered boring and less meaningful by students. It is because many elements that need to be memorized by students (Franco-Mariscal, 2015). By teaching REE topics through context-based learning. This can be a preparation for PCT to applying the same thing when someday become a chemistry teacher. PCT should be known that learning with context-rich is more meaningful than just learning by memorize.

4. Conclusion

The results show that PCT still had difficulties understanding the chemistry content related to REE, especially about the electronic configuration. This poor understanding of the electronic configuration impacts the learning difficulties encountered in understanding the magnetic and luminescence properties of REE. In addition, PCT still found difficulties in understanding the correlation between chemistry content and context in REE topic.

The difficulty always occurs in questions that need to be answered by comprehension, which about electronic configuration. From obtaining student opinions regarding the need for REE learning designs, all students gave positive impression the existence of REE learning designs for chemistry education students. 88.2% of students strongly agree with implementing REE learning design. Suggestions from this study are to give PCT further discussion about electronic configuration before learning REE topic. The next suggestion, REE topic should be designed with context-based learning. As closing statement, the results of this study provide a basic overview for the development of learning designs and teaching materials about REE that never developed.

References

Adesoji, F., & Omilani, N. (2012). A comparison of secondary schools students' levels of conception of qualitative and quantitative inorganic analysis. *American Journal of Scientific and Industrial Research*, *3*(2), 56–61. https://doi.org/10.5251/ajsir.2012.3.2.56.61

American Chemical Society. (2008). *ACS Guidelines for Bachelor's Degree Programs*. Retrieved from https://www.acs.org/content/acs/en/education/policies/acs-approval-program/guidelines-supplements.html

Anwar, B., Ernawati, S., Setiadi, R., & Wiji. (2012). Pengembangan Representasi Kimia Sekolah Berbasis Intertekstual Pada Sub-Konsep Konfigurasi Elektron Model Atom Bohr yang Diperluas dalam Bentuk Multimedia. *Jurnal Pengajaran Matematika Dan Ilmu Pengetahuan Alam (JPMIPA)*, *17*(278–285). https://doi.org/https://doi.org/10.18269/jpmipa.v17i2.36108

Atwood, D. A. (2012). *The Rare Earth Elements: Fundamentals and Applications*. Wiley.

Castor, S. B., & Hedrick, J. B. (2006). Rare Earth Elements. In *Industrial Minerals and Rocks* (7th ed., pp. 769–792). Society for Mining, Metallurgy, and Exploration.

Franco-Mariscal, A. J. (2015). Exploring the Everyday Context of Chemical Elements: Discovering the Elements of Car Components. *Journal of Chemical Education*, *92*(10), 1672–1677. https://doi.org/10.1021/acs.jchemed.5b00164

Franco-Mariscal, A. J. (2018). Discovering the Chemical Elements in Food. *Journal of Chemical Education*, *95*(3), 403–409. https://doi.org/10.1021/acs.jchemed.5b00164

Gurel, D. K., Eryilmaz, A., & McDermott, L. C. (2015). A review and comparison of diagnostic instruments to identify students' misconceptions in science. *Eurasia Journal of Mathematics, Science and Technology Education*, *11*(5), 989–1008. https://doi.org/10.12973/eurasia.2015.1369a

Hermanns, J. (2021). How do pre-service chemistry teachers rate the importance of content in organic chemistry during their chemistry studies at university? *Chemistry Teacher International*, *3*(4), 359–365. https://doi.org/10.1515/cti-2021-0004

Huang, C. (2010). Rare Earth Coordination Chemistry: Fundamentals and Applications. In *Rare Earth Coordination Chemistry: Fundamentals and Applications*. https://doi.org/10.1002/9780470824870

Jain, J., Lim, B. K., & Abdullah, N. (2013). Pre-service Teachers' Conceptions of the Nature of Science. *Procedia - Social and Behavioral Sciences*, *90*(InCULT 2012), 203–210. https://doi.org/10.1016/j.sbspro.2013.07.083

Jha, A. R. (2014). Rare earth materials: Properties and applications. In *Rare Earth Materials: Properties and Applications*. https://doi.org/10.1201/b17045

Kang, J., & Kang, A. M. (2020). Trend of the research on rare earth elements in environmental science. *Environmental Science and Pollution Research*, *27*(13), 14318–14321. https://doi.org/10.1007/s11356-020-08138-z

Klinger, J. M. (2018). Rare earth elements: Development, sustainability and policy issues. *Extractive Industries and Society*, *5*(1), 1–7. https://doi.org/10.1016/j.exis.2017.12.016

Lewis, E. B., Rivero, A. M., Lucas, L. L., Musson, A. A., & Helding, B. A. (2021). Setting empirically informed content knowledge policy benchmarks for physical science teaching. *Journal of Research in Science Teaching*, *58*(8), 1238–1277. https://doi.org/10.1002/tea.21709

Louise, I. S. Y., Sugiyarto, K. H., & Al, H. P. (2017). Identifikasi Miskonsepsi Konsep Kimia Dan Upaya Mengatasinya Melalui Chemistry Clinic Bagi Pada Guru Anggota Mgmp Kimia. *Jurnal Pengabdian Masyarakat MIPA dan Pendidikan MIPA*, *1*(2), 114-118. https://doi.org/10.21831/jpmmp.v1i2.15569

Mayring, P. (2015). Qualitative content analysis: Theoretical background and procedures. In *Approaches to qualitative research in mathematics education* (pp. 365–380). Springer, Dordrecht. https://doi.org/10.1007/978-94-017-9181-6_13

Miessler, G. L., & Tarr, D. (2013). *Inorganic Chemistry*. Pearson Education, Inc.

Niebert, K., & Gropengiesser, H. (2013). The model of educational reconstruction: A framework for the design of theory-based content specific interventions. The example of climate change. *Educational Design Research–Part B: Illustrative Cases*, 511–531. Retrieved from https://scholar.google.com/citations?view_op=view_citation&hl=id&user=BvidVroAAAAJ&citation_for_view=BvidVroAAAAJ:d1gkVwhDpl0C

Pinarbasi, T., & Canpolat, N. (2003). Students' Understanding of Solution Chemistry Concepts. *Journal of Chemical Education*, *80*(11), 1328–1332. https://doi.org/10.1021/ed080p1328

Redhana, I. W., Sudria, I. B. N., Hidayat, I., & Merta, L. M. (2017). Identification of chemistry learning problems viewed from conceptual change model. *Jurnal Pendidikan IPA Indonesia*, *6*(2), 356–364. https://doi.org/10.15294/jpii.v6i2.8741

Saputra, O., Setiawan, A., & Rusdiana, D. (2019). Identification of student misconception about static fluid. *Journal of Physics: Conference Series*, *1157*(3), 32069. Retrieved from https://iopscience.iop.org/article/10.1088/1742-6596/1157/3/032069/meta

Suma, K., Wayan Sadia, I., Made Pujani, N., & Ketut Rapi, N. (2019). Investigating students' preconception of some electromagnet topics. *Journal of Physics: Conference Series*, *1317*(1). https://doi.org/10.1088/1742-6596/1317/1/012203

Supiah YL, I., Sugiyarto, K. H., & Aloysius, H. P. (2017). Miskonsepsi Kimia, Modul Guru Pembelajar. *Jurnal Pengabdian Masyarakat MIPA Dan Pendidikan MIPA*, *1*(2), 114–118.

Suyanti, R. D., Arifin, M., & Martoprawiro, M. A. (2006). Pembekalan Kemampuan Generik Bagi Calon Guru Melalui Perkuliahan Kimia Anorganik Berbasis Multimedia. *Jurnal Pendidikan Matematika Dan Sains*, *11*(2), 107–112.

https://doi.org/10.21831/jpms.v11i2.12430

Tal, M., Herscovitz, O., & Dori, Y. J. (2021). Assessing teachers' knowledge: incorporating context-based learning in chemistry. *Chemistry Education Research and Practice*, *22*(4), 1003–1019. https://doi.org/10.1039/D0RP00359J

Voncken, J. H. L. (2016). *The Rare Earth Elements*. Springer International Publishing. https://doi.org/10.1007/978-3-319-26809-5

Wilson, C. (2014). *Chapter 2&4-Semi-Structured Interviews-Phone Interviews*. Interview Techniques for Ux Practitioners. C. Wilson.

Xiao, C., Cai, H., Su, Y., & Shen, L. (2020). Online Teaching Practices and Strategies for Inorganic Chemistry Using a Combined Platform Based on DingTalk, Learning@ZJU, and WeChat. *Journal of Chemical Education*, *97*(9), 2940–2944. https://doi.org/10.1021/acs.jchemed.0c00642