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Mapping chemistry learning difficulties of secondary school students: a cross-grade study

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ABSTRACT

Students' lack of interest in chemistry becomes a significant issue in chemistry learning. This may be caused by the negative perception of students about their difficulties in learning chemistry. This study aims to explore views and causes of difficulties in learning chemistry from the perspective of secondary school students. This research was designed using a survey method through a cross-grade study. The sample that participated in this study was 634 students from the grade 10, 11, and 12 (G10, G11, and G12) of secondary school students in Yogyakarta, Indonesia, through random sampling. The data in this study were collected using the chemistry difficulties scale (CDS) and chemistry perception questions (CPQ). Statistical descriptive techniques, a one-way multivariate analysis of variance (MANOVA) test, and content analysis, were used to analyse the research data. The results showed that the grade somewhat affected students' views towards chemistry. They viewed chemistry as a fairly difficult subject, with stoichiometry, thermochemistry, and macromolecule being among the most challenging topics in G10, G11, and G12, respectively. These difficulties are caused by scientific language, mathematical abilities, student abilities, and teacher competence in conducting chemistry lessons. Since the students consider chemistry somewhat difficult, chemistry teachers must take appropriate strategies to overcome these difficulties.

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1. INTRODUCTION

The lack of student interest in chemistry lessons is currently a major problem in chemistry education. The diminishing number of students choosing chemistry for their future studies or careers is one of the most prevalent problems that have occurred in countries [1], [2]. This pattern developed as a result of students' unfavourable attitudes toward chemistry. In Indonesia, the chemistry was included in the elementary school (grades 1-6) and junior high school (grades 7-9) curricula as an integrated science course. Since chemistry is given as an integrated science course for them, the students are only introduced to a little and fundamental concept of chemistry, and it is correlated with students' everyday life (e.g., additives and addictive concepts). In contrast, chemistry is studied as a separate course from other science subjects in secondary schools (grades 10-12), such as physics and biology. Secondary school students could major in social science, language, or pure science. As a result, chemistry is a required course for students majoring in science for ten grade students (G10), eleven grade students (G11), and twelve grade students (G12). In

addition, chemistry curricula for these grades were developed following to systemic characteristics of the chemistry concept. This means that students need to master previous chemistry materials before they study the following chemistry concepts. Thus, it is argued that students in each grade of secondary school have different views toward chemistry lessons. In fact, the majority of chemistry students, at the secondary school level and the university level, have difficulty learning this subject. Unfortunately, many of them fell short afterward [3]. According to the results of recent studies, many students are still having trouble comprehending chemistry's core ideas. Additionally, many of them held preconceptions before enrolling in college [4]. Without a solid grasp of the fundamental concepts, the students will struggle to comprehend the more complex concepts of advanced chemistry, which lead to the misconception [5]–[7]. In order to identify the barriers to students' success in learning chemistry, it is crucial to investigate their perceptions of the chemistry subject.

The students' perceptions of chemistry are crucial because these perceptions let students imagine the calibre of the learning activities that take happened in chemistry. Perception is one of the main learning objectives in chemistry because it reflects attitudes toward chemistry-related disciplines [8]. According to Fitriyana *et al*. [9], perception is related to students' views, whether positive or negative, on a particular emotion. Thus, students must evaluate how they feel about chemistry ideas in this situation. Previous studies have revealed that chemistry is one of the most complex science subjects [10]. At the same time, Treagust *et al*. [11] and Woldeamanuel *et al*. [3] demonstrated that teaching chemistry is just as challenging as learning it. Students learning chemistry need to comprehend what and how the principles of chemistry work, as well as why it is important to study these concepts. As a result, how students perceive their chemistry classes will reveal how they view chemistry. Unfortunately, very few researchers only a handful have looked at the root causes of students' learning challenges. However, in order to find the most effective course of action to lessen students' problems and increase their performance in studying chemistry, it is important to map out the causes of their learning challenges. Numerous investigations reported that the most difficult area in learning science caused by the abstract nature [12], [13], the requirement of mathematical skills [10], unfamiliar language and symbol [11], lack of motivation [13], and lack of teacher competencies [1].

In terms of chemistry learning content, Sokrat *et al*. [13] assert that mastering chemistry concept demands a high level of comprehension, consideration, and reasoning. According to earlier research, the concept of *moles*, chemical reaction equations, organic chemistry, molecular geometry, and condensation are among the chemistry learning lesson that is seen as challenging [14]. The abstractness of chemistry content that is not easy to visualize, such as molecular geometry topic makes students difficult to understand this topic. Meanwhile, the need for mathematical skills in doing calculations in the concept of moles and chemical reaction equations and the strange symbols (e.g., chemical formula) in organic chemistry is another factor that might become the source of difficulty in learning chemistry for students.

Phrased differently, even though chemistry lessons are conceptual in nature, the chemistry learning content arranged in the curriculum is presented coherently according to a logical sequence. For example, whether at the secondary school level or university level, chemistry learning content begins with atomic theory, line spectrum, Schrodinger equation, hybridization orbitals, chemical bonds, compound formulas, reaction equations, to stoichiometry [15]. Therefore, it takes a professional and experienced teacher who is sufficient to design coherent chemistry learning activities. However, the facts show that teachers have varied pedagogical competencies. As the spearhead of implementing chemistry learning activities, teachers are expected to have good pedagogical competence. This relates to the teacher's need to design strategies in such a way as make the delivery of chemistry material attractive to students [16]. Unfortunately, most of the teachers do not have good pedagogical skills yet. Learning is carried out in a teacher-centered situation so that students become passive, not eager to think, and only receive information from the teacher [17]. Interestingly, the most prominent contribution is a decline in the number of students reluctant to learn chemistry because they feel that chemistry has less application in daily life [12]. They cannot correlate the chemistry concepts they learn in school and their application in their everyday life [18]. Such learning of chemistry becomes less meaningful, so it does not guarantee a good understanding of students. This fact may be the cause the students' interest in chemistry to decrease because they consider chemistry learning activities to be boring. In addition, exploring the perceptions of students on chemistry subjects and the factors that cause them is essential to be done because these findings could help the teachers in arranging more meaningful chemistry learning for them.

There are several related studies that examine the perspective of difficulties in chemistry from the view of pupils at junior high school [1], [5], [11] senior high school [5], [8], [14], vocational high school [9], and university students [3], [11], [14]. Some of them employed quantitative studies [8], [10] and other utilized qualitative approach in order to explore students' difficulties in chemistry [1], [3], [11]. These qualitative studies examine the reasons why chemistry is considered a difficult subject (e.g., abstract properties of chemistry content, students' motivation, and teachers' competencies). Perhaps, these kinds of

difficulties could be overcome by constructing certain pedagogies. Taking an example, the use of learning media in chemistry (e.g., augmented reality and virtual laboratory [19]); appropriate learning strategy (e.g., context-based learning [20], SSI based instruction [21], case-based learning [22]); and modifying learning content (e.g., multiple representation in chemistry [23]) are needed to achieve meaningful chemistry learning. However, none of them examine students' difficulties in learning chemistry subjects across the grade and collect the quantitative and qualitative data at the same time. That is, chemistry teachers should know what type of chemistry content is regarded as a challenging concept by secondary school students in each grade. Therefore, to meet this issue, a mapping of students' difficulties in learning chemistry is needed in order to pick the most effective way to design chemistry learning activities. This study not only mapping which concepts in chemistry is considered difficult by students but also to explore the reason why those concepts are regarded as challenging on each grade of secondary school students. Thus, this research focused on answering the following research questions.

- How are secondary school students' views towards chemistry subject?
- Are there differences in students' views towards chemistry subject based on their grades?
- What makes chemistry considered a difficult subject by secondary school students?

2. METHOD

2.1. Research design

This research employed a cross-grade survey with a combination of quantitative and qualitative approaches. Thus, there was no intervention during the data collection process. This study intended to capture secondary school students' views towards chemistry subject in one-time interactions amongst groups in order to understand how the grade as a year of the study could affect their views towards chemistry [24]. Through this research design, we explore not only the perceptions of secondary school students on chemistry subjects but also the cause they considered chemistry as a difficult subject.

2.2. Research sample

The chemistry in secondary school is studied by students majoring in science as a mandatory subject. The samples used in this study were 634 secondary school students at public and private secondary schools majoring in science in Yogyakarta, Indonesia following random sampling technique. They varied in grades and gender as shown in Table 1.

Table 1. Distribution of the sample

Sample	Male	Female	Total
1st year (G10)	99	108	207
2nd year (G11)	92	116	208
3rd year (G12)	106	113	219
Total	297	337	634

Since this study involved human participants, as ethical consideration, the data collection process was conducted after the secondary schools had approved legal permission. The research samples voluntarily agreed to become the research samples in this study. This means that all of the research samples were given permission to publish the research finding.

2.3. Data collection tools and research instruments

The chemistry difficulties scale (CDS) and chemistry perception questions (CPQ) were administered to collect students' perceptions of chemistry. The CDS was used to reveal students' views toward chemistry subjects based on their grades. Meanwhile, the CPQ was used to explore the reason why they considered chemistry a difficult subject. The CDS used 4 Likert-type scales with the assessment categories ranging from strongly disagree to strongly agree. The CDS was developed by researchers by synthesizing factors that cause chemistry contents to be considered difficult subjects from various works of literature. The CDS consisted of 37 items (15 negative and 22 positive items) and were well distributed into four factors, including i) learning environment with three items, ii) learning content with 17 items, iii) students' motivation with 11 items, and iv) teachers' competencies with six items. The CDS, in brief, is presented in Table 2.

On the other hand, the CPQ was prepared to explore four main issues: i) perception about students' difficulties in chemistry, ii) cause of difficulties in chemistry, iii) effort to overcome their chemistry learning difficulties, and iv) chemistry content that is considered difficult. This CPQ was only given for G12 secondary school students because they have learned all of the chemistry materials for the secondary school level. The CPQ blueprint seen in Table 3.

Table 2. Blueprint of the CDS

Factor	Indicator	No of item	Example of item
Learning environment	Infrastructure support to organize chemistry learning	3	The limited media and visual aids made chemistry subjects difficult for me to understand
Learning content	Most of chemical concepts are abstract	2	The abstractness of chemistry concepts makes me difficult to learn chemistry.
	Students' argumentation skills to solve chemical problems	2	My poor argumentation ability causes difficulties in explaining chemical concepts.
	Symbols, terms, and scientific language used in chemistry concepts	3	The terms used in chemistry are very strange to me
	Mathematical ability to solve chemical problems	3	My mathematical ability is relatively low, so I have difficulty mastering the concept of stoichiometry
	The connection between the understanding of one chemical concept and another	3	The relationship between one concept and another is my weakness in understanding chemistry concepts
	The usefulness of chemistry in life	4	The chemistry material that was taught is related to everyday life, so I can easily understand chemistry
Students' motivation	Students' motivation in understanding chemistry concepts	4	I did my best to master chemistry concepts
	Students' interest in learning chemistry	4	I want to learn more about chemistry
	The enthusiasm of students in participating in chemistry lessons	3	I am excited to take part in chemistry lessons, so I do all the assignments given.
Teachers' competencies	Teacher pedagogical competence in designing chemistry lessons	3	My teacher was not able to explain chemistry well, so I had difficulty understanding chemistry.
	The learning strategy applied by the teacher	3	The learning strategy used by the teacher can increase my motivation to learn chemistry.

Table 3. Blueprint of the CPQ

Dimension	No	Question
Perception about students' difficulties in chemistry	Q1	In your opinion, is chemistry difficult, moderate, or easy to understand? Give an explanation!
Cause of difficulties in chemistry	Q2	If chemistry is difficult to understand, what are the main causes of chemistry being a difficult subject? Give your opinion!
Efforts to overcome chemistry learning difficulties	Q3	What can you do to overcome difficulties in studying chemistry? Explain!
Chemistry content that is considered difficult	Q4	Look at the chemistry concepts for grades 10-12, then determine the most difficult topic in each grade. Give your reasons why this concept is the most difficult concept.

Furthermore, before the instruments were used to collect research data, the validity and reliability analysis of the instruments were carried out. The CDS and CPQ followed content and face validity by asking the judgments from a total of 6 experts in the field of chemistry and chemistry education. They gave feedback, and some of the necessary revisions regarding the suitability of items with their indicators, sentence construction, and appropriate Indonesian grammar rules have been accomplished by the researcher. In addition, the researchers also performed empirical validity of CDS by administering the CDS to 449 secondary school students who did not take part in the real study. The findings of the empirical study were then analysed following confirmatory factor analysis (CFA), and it showed that the CDS with four factors was appropriate for assessing secondary school students' views toward chemistry subject. The estimated reliability Cronbach Alpha value was found to be 0.916, which means that it is higher than the acceptable value proposed by Hair *et al*. [25]. Therefore, the pilot study showed that the CDS is a reliable and valid scale to collect data on the views regarding chemistry lessons from secondary school students.

2.4. Data analysis

Since the CDS covered positive and negative items, thus; there was two scoring technique (e.g., 4-1 for positive items and 1-4 for negative items). The data analyses employed in this study were descriptive statistics, the one-way multivariate analysis of variance (MANOVA) test, and the combination of interpretive and inductive content analysis. Category analysis with descriptive statistics was used to answer the first research question, which was to analyse the categories of secondary school students' views towards chemistry subjects. The final average score for the perception of secondary school students obtained in each sample was categorized into four categories ranging from *excellent* (mean score ≥3), *good* (2≤ mean score <3), *poor* (1≤ mean score <2), and *very poor* (mean score <1). Each category was then calculated the frequency and made a percentage. After that, the data of secondary school students' views towards chemistry subjects were imported into SPSS 25.00™ to run the One-way MANOVA test. The purpose of this test was to examine the

significant difference in secondary school students' view towards chemistry as a dependent variable across the grade (G10, G11, and G12) as the independent variable. In addition, content analysis with the combination of interpretive and inductive coding aims to study in depth the perceptions of secondary school students' difficulties in chemistry subjects. Responses obtained from CPQ were coded and grouped into more specific themes and presented in frequency and percentage.

3. RESULTS AND DISCUSSION

3.1. Findings

According to the data obtained from CDS, the descriptive statistics consisting of students' mean score, standard deviation, maximum, and minimum score of secondary school students' views towards chemistry subject were presented in Table 4. From Table 4, it shows that G12 of secondary school students have a better view of chemistry subjects (mean score 2.685). This is followed by G11 students (mean score of 2.623) and then G10 students (mean score of 2.579). Thus, G10 students of secondary school have the poorest views toward chemistry compared to students with higher grades.

Table 4. Descriptive statistics data

Research sample	Factor	N	Mean	SD	Max score	Min score	Maximum ideal score
G10	Overall	207	2.579	0.357	3.742	1.546	4.000
	Learning environment		2.290	0.526	4.000	1.000	4.000
	Learning content		2.538	0.340	3.778	1.389	4.000
	Students' motivation		2.811	0.463	4.000	1.222	4.000
	Teachers' competencies		2.678	0.565	4.000	1.000	4.000
G11	Overall	208	2.623	0.314	3.704	1.440	4.000
	Learning environment		2.415	0.524	4.000	1.000	4.000
	Learning content		2.557	0.284	3.611	1.667	4.000
	Students' motivation		2.729	0.457	4.000	1.222	4.000
	Teachers' competencies		2.792	0.445	3.857	1.429	4.000
G12	Overall	219	2.685	0.379	3.944	1.627	4.000
	Learning environment		2.420	0.548	4.000	1.000	4.000
	Learning content		2.610	0.356	3.833	1.778	4.000
	Students' motivation		2.836	0.457	4.000	1.444	4.000
	Teachers' competencies		2.874	0.579	4.000	1.000	4.000

3.1.1. Secondary school students' views towards chemistry subject

The findings of secondary school students' views towards chemistry confirmed the descriptive statistics data results. Secondary school students' views towards chemistry in each grade were grouped into four categories as shown in Table 5. Examining the data in Table 5, it was clear that as the grade increased, secondary school students' views towards chemistry improved. In detail, most of the G10 students have a better view of chemistry based on their motivation to learn chemistry. Meanwhile, teachers' competency is the factor that makes the G11 and G12 of mostly secondary school students' views towards chemistry better.

Table 5. Secondary school students' views towards chemistry subject

Factor	Category	G10		G11		G12	
		f	%	f	%	f	%
Overall	Excellent	17	8	19	9	33	15
	Good	177	86	184	88	184	84
	Poor	13	6	5	2	1	1
	Very poor	0	0	0	0	0	0
Learning environment	Excellent	29	14	46	22	46	21
	Good	139	67	131	63	140	64
	Poor	39	19	31	15	33	15
	Very poor	0	0	0	0	0	0
Learning content	Excellent	22	11	16	8	32	15
	Good	178	86	190	91	186	85
	Poor	7	3	2	1	1	0
	Very poor	0	0	0	0	0	0
Students' motivation	Excellent	76	37	54	26	85	39
	Good	126	61	144	69	133	61
	Poor	5	2	10	5	1	0
	Very poor	0	0	0	0	0	0
Teachers' competencies	Excellent	67	32	80	38	118	54
	Good	121	58	122	59	91	42
	Poor	19	9	6	3	10	5
	Very poor	0	0	0	0	0	0

3.1.2. Differences in students' views towards chemistry subject based on their grade

Even though secondary school students' views towards chemistry are different based on the mean score across the grade, there was a need to run a statistical analysis to conclude statistically significant differences among the samples. The findings of one-way MANOVA examining the differences in students' views towards chemistry subjects based on their grades are observed in Table 6. Observing Table 6, it showed that there was a statistically significant difference among students' views towards chemistry subject across their grade. Statistically significant differences were also found in the factor of learning environment, students' motivation, and teachers' competencies. However, there was no statistically significant difference in the factor of chemistry content.

Table 6. Differences in students' views towards chemistry subject based on their grade

Test	Pillai's Trace	Test of between subject effects			
		Learning environment	Learning content	Students' motivation	Teachers' competencies
F	4.149	4.250	2.667	3.060	7.555
P*	0.000	0.015	0.070	0.048	0.001
Partial eta squared	0.026	0.013	0.008	0.010	0.023
Conclusion*)	Significantly different	Significantly different	No different	Significantly different	Significantly different

*) significance level of 0.05

3.1.3. Factors that make chemistry considered as difficult subject by secondary school students

The data from CPQ was used to investigate secondary school students' perspectives on the reasons behind their struggles in chemistry classes. The first question of CPQ was: *in your opinion, chemistry is difficult, moderate, or easy to understand?* Give an explanation! The responses from secondary school students revealed that most of them considered chemistry as a very difficult subject (33%). This number was followed by nearly a third of them that regarded chemistry as somewhat difficult, and almost 30% of them argued that it is easy, with the rest of them did not gave a response towards this question, as can be observed in Table 7.

Table 7. Views on chemistry subject

Category	f	%
Easy	64	29
Somewhat difficult	65	30
Very difficult	72	33
n/A	18	8

A total of 72 G12 of secondary school students that regarded chemistry as a difficult subject then explored more deeply the following questions on CPQ. These 72 students were anonymously identified as *S1, S2, ...* until *S72*. The Q2 directed to these secondary school students was: *if chemistry is difficult to understand, what is the main cause of chemistry being a difficult subject? Give your opinion!* The answers to this question were coded into ten categories, shown in Table 8. Witnessing the findings in Table 8, it is clear that the primary barrier to secondary school students' understanding of the subject matter of chemistry is scientific language. In addition, the majority of them have identified mathematical aptitude, student aptitude, and instructor competency as other contributing factors.

Table 8. Main causes of difficulty in chemistry subject

Codes	Participants	f	%
Scientific language	S1, S12, S2, S21, S24, S25, S26, S28, S29, S3, S30, S31, S39, S43, S44, S45, S50, S51, S52, S54, S8, 66, 67, 68	24	33.33
Lack of facilities	S13, S22, S27	3	4.17
Mathematical ability	S11, S14, S40, S46, S48, S53	6	8.33
Students' ability	S10, S23, S47, S32, S33, S35, S37, S49, S60	9	12.50
Teachers' competencies	S15, S16, S17, S61, S36, S62, S63, S64, S9	9	12.50
Hierarchical of chemistry concept	S20, S34, S42, S6	4	5.56
Abstractness chemistry concept	S18, S5, S7, 69, 70, 71, 72	7	9.72
Curriculum load	S65, S55, S56	3	4.17
Students' motivation	S57, S58, S59	3	4.17
n/A	S4, S19, S38, S41	4	5.56

The next question on CPQ was related to the efforts that students can undertake to overcome challenges in learning chemical concepts after the primary causes of chemistry being a topic that is difficult to understand. Independent study, discussing with peers or teachers, doing laboratory work, doing exercise regularly, and n/A for answers that did not fit into any of the aforementioned categories were used to classify student replies to this question. Table 9 displays the findings of the investigation together with the frequencies and percentages of these questions. Table 9 shows that the majority of students (64%) prefer to study individually by consulting different sources or watching chemistry instructional videos in order to get through their chemistry challenges. Discussing with peers or teachers about challenging chemistry topics that they do not master yet becomes an alternative way for secondary school students to overcome their difficulties in learning chemistry.

Table 9. Student efforts to overcome difficulties in understanding chemical concepts

Codes	f	%
Independent study	46	64
Discuss with peers and teachers	14	19
Doing exercise regularly	8	11
Laboratory work (experiment)	1	1
n/A	3	4

The last question on CPQ focused on the question about mapping secondary school chemistry topics that is most challenging to learn in each grade (G10, G11, and G12). Table 10 displays the distribution, frequency, and proportion of students for each chemistry topic. According to almost half of the participants (44.44%), stoichiometry is among the most challenging chemistry topics in secondary school G10, as can be witnessed in Table 10. The topic of thermochemistry, according to almost one-third of the participants (30.56%), was the most challenging for 2nd-year students' chemistry materials. Furthermore, macromolecules are the most difficult topic to study in the G12 of secondary school, according to 30.56% of students who participated in this study.

Table 10. The most difficult chemistry concepts for each grade according to secondary school students' opinion

Codes	Participants	f	%
Grade 10			
Atomic theory	S21, S45	2	2.78
Electron configuration	S30, S43, S49	3	4.17
Chemical bonding	S13, S14, S52, S53, S7	5	6.94
Molecular geometry	S12, S25, S26, S29, S33, S51, S61, S62, S63, S64, S65, S66, S67, S68, S69, S70, S71, S72	18	25.00
Electrolyte solution	S4, S5, S19	3	4.17
Redox reaction	S8, S18, S44	3	4.17
Stoichiometry	S1, S11, S16, S17, S2, S22, S27, S28, S3, S31, S32, S34, S35, S36, S37, S38, S39, S40, S41, S42, S46, S47, S48, S50, S6, S9, S55, S56, S57, S58, S59, S60	32	44.44
All of chemistry topic are difficult	S23, S54	2	2.78
n/A	S10, S15, S20, S24	4	5.56
Grade 11			
Hydrocarbon	S8, S22, S50	3	4.17
Thermochemistry	S13, S14, S2, S25, S26, S29, S3, S32, S33, S36, S39, S41, S45, S55, S56, S57, S58, S59, S60, S61, S62, S63, S64	22	30.56
Reaction rate	S12, S19, S31, S34, S44, S47, S53	7	9.72
Chemical equilibrium	S21, S27, S35, S46, S49, S51, S52, S6, S7, S65, S66, S67, S68, S68, S70, S71, S72	18	25.00
Acid and base	S30	1	1.39
Salt hydrolysis	S4, S43	2	2.78
Buffer solution	S1, S11, S16, S17, S18, S28, S38, S40, S42, S48, S5, S9	12	16.67
All of chemistry topic are difficult	S23	1	1.39
n/A	S10, S15, S20, S24, S37, S54	6	8.33
Grade 12			
Colligative properties of solution	S18, S38, S45	3	4.17
Balancing redox reaction	S19, S21, S37, S39, S40, S44	6	8.33
Voltaic cell	S14, S26, S30, S35, S47, S55	7	9.72
Electrolysis	S32	1	1,39
Chemical elements	S31, S41, S48, S5, S52	5	6.94
Functional groups of carbon compounds	S25, S27, S29, S33, S4, S7, S8, S65, S66, S67, S68, S69, S70, S71, S72	15	20.83
Macromolecule	S1, S12, S13, S2, S22, S28, S3, S34, S36, S43, S46, S50, S53, S6, S56, S57, S58, S59, S60, S61, S62, S63, S64	22	30.56
All of chemistry topic are difficult	S11, S23, S42, S49, S51, S54	6	8.33
n/A	S10, S15, S16, S17, S20, S24, S9	7	9.72

3.2. Discussion

3.2.1. Secondary school students' views towards chemistry subject

The findings of this research revealed that secondary school students' attitudes toward chemistry were improving as their grades rose (Table 5). According to their enthusiasm to learn chemistry, the majority of G10 students have a better perspective on chemistry. The factor that improves students' perspective towards chemistry in the G11 and G12 of largely secondary school students is teachers' competence. As can be seen in Table 5, in the factor of learning content, there was a slight decline in students' views towards chemistry. However, as they enter the G12 of secondary school, their views towards chemistry are improving. In fact, the decline in the number of students choosing chemistry for further fields of study or future careers is a problem that often occurs in almost all countries [1]. This can be caused by many factors, including the perceptions of students and teachers toward chemistry subjects. Basically, students' views of chemistry are relatively good. This has the implication that student perceptions based on the chemistry learning environment, student motivation, and the majority of teacher competence are good. However, based on the content of learning, chemistry still needs to be improved. They consider that there is some relatively easy chemistry subject content, but some other topics are difficult. Students' difficulties with some of these chemistry topics can influence reducing students' interest in learning chemistry [26]. Therefore, chemistry teachers should have good teachers' competencies in designing chemistry learning that is suitable for each type of chemistry learning content [27], [28].

In the factor of teachers' competencies, the G10 students have a lack of views towards their chemistry teachers compared to the other two grades of secondary school students. This shows that chemistry teachers have low self-efficacy in organizing chemistry lessons. Therefore, teachers' professional development program is needed for them to increase self-efficacy in teaching chemistry [29]–[32]. Good self-efficacy has been shown to have a significant contribution to student chemistry learning outcomes [33]. Furthermore, the chemistry learning environment such as the availability of laboratory facilities and media in chemistry learning is urgently needed to carry out meaningful and innovative chemistry learning [34]–[36].

3.2.2. Differences in students' views towards chemistry subject based on their grade

It had a small impact size with partial eta squared (η^2) accounting for 0.026 despite statistically significant differences being observed between grade and the dependent variable (their views towards chemistry topic with the four factors of the CDS scale) ($p<0.05$) (see Table 6). This implies that perceptions of chemistry among secondary school students vary somewhat according to grade. Hence, an increase in grade has resulted in a linear improvement in secondary school students' views toward chemistry. Additionally, there is a slight correlation between grades and attitude toward the topic of chemistry. Although while the grade is regarded as a sign of maturity, it has little to no impact on the evolution of attitudes towards chemistry subject. Intriguingly, the CDS scale's *"chemistry content"* variables were unaffected by the grade as a source, but these factors were highly impacted by the *"learning environment, students' motivation, and teachers' competence*."

For the factor of *"learning environment"* statistical differences appeared among secondary school students in different grades. This means that an incline in grades seems to have supported students' views toward chemistry. In this case, the learning environment consisted of facilities that students encountered during their chemistry lessons, such as laboratory equipment, computer-based media, and resources they could access. This significant difference occurred between the G10 student in favour of the G11 and G12 students. As could be explored in the chemistry curriculum, for the G10 students, the chemistry materials that were delivered were mostly theoretical in nature. Thus, they have limited experience in learning chemistry with such support of a learning environment. For instance, the chemistry laboratory work activity for the G10 of secondary school students could be done in stoichiometry, electrolyte and non-electrolyte solutions, and redox reaction materials. However, they are several chemistry teachers for ten graders who cannot prepare laboratory work activities for students due to the lack of availability of laboratory equipment [19]. This may also come from the lack of competence of chemistry teachers in preparing laboratory activities. That is, limited experiences for G10 students in dealing with learning environments that support chemistry lessons may have driven them to show fairly views towards chemistry subjects.

Similarly, this argument is valid for the *"teachers' competence"* factor that incorporated significant differences between grades in favour of G12 students ($p<0.05$). Teacher competencies play a pivotal role in constructing students' views toward chemistry because chemistry teachers are the direction in holding chemistry lessons. Innovations that have the potential to be applied in chemistry learning include using a student-centred learning paradigm, introducing contextual chemistry learning, and small group work [37], [38]. For this reason, chemistry teachers should have a good pedagogical content knowledge (PCK) because their PCK allows significant implications for student-teacher education in designing a variety chemistry learning strategy [39], [40]. Thus, bringing the relationship between pedagogical knowledge and content

knowledge in chemistry lessons should be built since they were in a teacher education program. Chemistry educators should take into account regarding how to best address graduate attributes when they are participating in teacher education program. Not only in the terms of pedagogical competencies, but also value the content of chemistry to foster their literacy and integrate it into their teaching [41]. Examining the findings of this researchm it implied that students in the G12 have a better view of chemistry due to teachers' competency means that they viewed their chemistry teacher as having good skills in arranging chemistry lessons. In this case, G12 students could compare teachers' performance when they were in the G10 and G11 of their study.

Likewise, the factor of *"students' motivation"* in the CDS scale conveyed significant differences in favour of G10 and G12 of secondary school students ($p<0.05$). This indicates that an increase in grades has improved their views toward chemistry lessons. The findings of this research confirmed Schluter's [42] that students with lower grades show a huge enthusiasm for learning than those at the senior level. The G10 students have their first experience studying chemistry as a separate subject; thus, they have a good enthusiasm to study chemistry and show their curiosity [43]. However, when students enter a G11, their motivation to study chemistry is declined due to chemistry content in a G11 that is mostly related to calculations. Most students encountered difficulties in doing calculations and comprehending basic chemistry concepts that had abstract characteristics. Having less relevance to chemistry content and their lives causes students to show less interest in studying chemistry. That is, chemistry teachers should manage their teaching in order to increase the relevance of chemistry materials to the everyday lives of students. This view was totally contradicted when the students entered the G12 of secondary school. Their motivation to study chemistry was dramatically improved because there was preparation for college that would determine their future career.

Nevertheless, the factor of *"chemistry content"* signified no difference across the grade of secondary school students ($p>0.05$). This means that even though students across the grade have different experiences in studying chemistry in terms of the length of the study and the materials they have learned, they have similar views towards chemistry content. To illustrate, most of the chemistry content for the G10 student is the theory (e.g., atomic theory, chemical nomenclature, and redox reaction), mostly calculations for G11 students (e.g., thermochemistry, reaction rate, and chemical equilibrium), and combination of theory and calculation (e.g., colligative properties of the solution, and chemical elements.) for G12; but they have similar views towards chemistry. This finding conveyed that secondary school students across their grades showed somewhat similar motivation to study chemistry. Nevertheless, it is argued that as the grade increase, their views toward chemistry content is enhanced. Therefore, to foster students' views towards chemistry, an appropriate learning environment, motivation, and teacher competencies are needed, together with students' enthusiasm for studying chemistry [44].

3.2.3. Factors that make chemistry considered as difficult subject by secondary school students

Before further exploring the causes of students' difficulties in chemistry, the researcher first examined students' perceptions of chemistry. Based on Table 7, it can be concluded that some students consider chemistry easy (29%) and somewhat difficult to be learned (30%). However, almost a third of the G12 of secondary school students think that chemistry is a difficult subject (33%). The results of this study confirm the results of previous research conducted by Cardellini [1] and Woldeamanuel *et al*. [3], who find that chemistry subjects are difficult to study.

The main cause of students' difficulties in chemistry is scientific language. The participants mentioned that the chemistry lesson contained many symbols, chemical reactions, compound names, and foreign terms for them. The results of this study support the results of previous relevant research that the unfamiliar language of science for students is the main obstacle to understand chemistry material [45], [46]. Apart from scientific language, mathematical ability, student ability, and teacher competency are other causative factors formulated by most of the participants in this study. With regard to mathematical abilities, it is undeniable that topics in chemistry involve formulas and calculations, so good mathematical abilities are important [10]. Most of the participants also said that they had weak mathematical abilities, so they had difficulties when they had to face chemistry topics that involved calculations. As for teacher competence, chemistry teachers must have good PCK to teach chemistry because the lack of teacher competency makes chemistry learning less meaningful [10]. Therefore, bridging the correlation between chemistry and problems in life is crucial [47], [48].

After the perceptions and factors that cause students' difficulties with chemistry are revealed, the researchers explore the efforts made by students to overcome their difficulties in understanding chemistry concepts. Majority of students (64%) prefer to study independently by looking for various references or watching chemistry learning videos to overcome their difficulties in chemistry. They did this in an effort to understand the chemical content, which they found difficult. In addition to independent study, students also try to discuss with their peers and chemistry teacher as another way to understand chemistry subjects.

Through these discussion activities, students can share experiences and knowledge and bring new insights into understanding chemical concepts [49].

Furthermore, this research also explores chemistry topics that are considered the most difficult for students for each grade in secondary school. Stoichiometry is among the most difficult chemistry topics in the G10 of secondary school, based on almost half of the participants' opinions (44.44%). This finding confirmed previous research that the main challenge in the stoichiometry is the lack of prior knowledge regarding that linked with basic knowledge of other chemical concepts [50], [51]. Almost a third of the participants (30.56%) stated that the topic of thermochemistry was the most difficult in the G11 of secondary school. This is because the topic of stoichiometry and thermochemistry involves many formulas, calculations, and a lot of scientific language and chemical equations [45]. Furthermore, macromolecules are the most difficult topic to study in the G12 of secondary school, according to 30.56% of students who participated in this study. Most of the participants stated that macromolecules have many theoretical concepts. To meet this issue, exploring reasoning ability seems to be the potential to promote students' understanding of chemistry [52].

4. CONCLUSION

In light of this study, it can be concluded that secondary school students thought chemistry was a challenging topic, although their impressions of it fell into the "good" category. Also, it can be inferred that their views of chemistry in secondary school were somewhat influenced by grades. Most of the students' chemistry problems are brought on by problems with scientific language, math skills, student ability, and teachers' competency to teach chemistry. According to most secondary school students the topic of stoichiometry, thermochemistry, and macromolecule are among the most difficult chemistry topics in secondary school's G10, G11, and G12. Since the students find chemistry to be somewhat challenging, chemistry educators must employ the proper strategy to get beyond these challenges.

This study explored a comprehensive perspective of secondary school students towards chemistry subjects by combining the findings of quantitative and qualitative data in interpreting the results and comparing the perspective across the grade of students. For future research, it is recommended to study secondary school student’s perspective towards chemistry in specific chemistry topics that are considered difficult based on the finding of this research. Therefore, more specific solutions would be proposed to tackle these difficulties and improve students' learning outcomes.

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