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What do Students Know About Green Chemistry? Evidence from a Survey of Pre-Service Chemistry Teacher

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Abstract

The application of Green Chemistry (GC) is increasing at the university level. This study focuses on measuring the knowledge of pre-service chemistry teachers about the principles of GC. The instrument used is the Assessment of Student Knowledge of Green Chemistry Principles (ASK-GCP). The instrument is 24 questions in multiple true-false formats about the principles of GC. The data were collected between May and June 2022. The total sample was 90 students. The data was analyzed using Rasch Model with Winsteps 5.1.2. The interaction between the person and the item shown on the Wright map. 44.5% of students in the high category of knowledge about GC. The result of this survey can be used as a reflection for students and instructors about GC knowledge.

Keywords: green chemistry; pre-service chemistry teacher; wright map; ASK-GCP

Abstrak

Penerapan Green Chemistry (GC) semakin meningkat di tingkat universitas. Konsep GC perlu diterapkan dalam pembelajaran kimia di sekolah dan perguruan tinggi khususnya dalam kegiatan praktikum di laboratorium. Penelitian ini berfokus pada pengukuran pengetahuan calon guru kimia tentang prinsip-prinsip GC. Instrumen yang digunakan adalah Assessment of Student Knowledge of Green Chemistry Principles (ASK-GCP). Instrumen terdiri dari 24 pertanyaan dalam format benar-salah tentang prinsip-prinsip GC. Data dikumpulkan antara bulan Mei hingga Juni 2022. Sampel berjumlah 90 oarang mahasiswa. Data dianalisis menggunakan Model Rasch dengan aplikasi Winsteps 5.1.2. Interaksi antara pengetahuan mahasiswa dan item yang ditampilkan pada Wright Map. Hasil survei menunjukkan bahwa 44,5% mahasiswa memiliki pengetahuan GC dalam kategori tinggi. Hasil survei ini dapat digunakan sebagai refleksi bagi mahasiswa dan pendidik tentang pengetahuan GC.

Kata kunci: green chemistry; calon guru kimia; wright map; ASK-GCP

Introduction

Indonesia is adapting to world technological developments. The rapid growth of technology has a positive and negative impact, especially on environmental condition in one. One of the efforts to overcome environmental problems, Indonesia began to launch sustainable development concept. This concept aims to meet the current and future needs of the nation's next generation. Sustainable development has been proclaimed and applied to all aspects of life, including education (Hamidah et al., 2017).

There are ten essential issues confronted by human beings withinside the subsequent 50 years, particularly energy, food, water, environment, terrorism and war, poverty, education, disease, population, and democracy. Five of the 10 issues, particularly energy, water, food, environment, and disease. There are intently associated with chemistry and might best be solved with a brand new chemical concept, mainly Green Chemistry (Winterton, 2021).

The application of Green Chemistry (GC) in teaching is an essential issue in the field of chemistry education. GC is an area of chemistry that focuses on the design of chemical products and processes that reduce hazardous substances (Chen et al., 2020). Therefore, it is impmitigate to reduce chemical-related impacts on human health and pollution (Zuin et al., 2021). GC also tries to apply the use of innovative and environmentally friendly chemicals (Chen et al., 2020), alternative reaction media, take the place of of toxic solvents and the application of various "greener" approaches that incorporate the 12 main principles of GC (Ivanković et al., 2017).

Various studies have introduced the GC in curriculum and teaching (Zuin et al., 2021). The principle of GC is likewise delivered to school college students with the aid of using the usage of case-primarily based gaining knowledge of modules (Ballard & Mooring, 2021; Kennedy, 2016). In addition, designing a GC course for undergraduates, college students learn how to observe the standards of GC thru case research and journal article activities, even as linking most of these sources and reports with concept maps (Kennedy, 2016). Also, the research introduced education for sustainable development in undergraduate laboratories (Srivastava & Sharma, 2021; Winterton, 2021). Several articles have also reviewed the application of GC in teaching and learning activities (Chen et al., 2020; Marques et al., 2020; Savec & Mlinarec, 2021).

There are twelve principles of GC, namely: waste prevention, atomic economy, less dangerous chemical synthesis, creation of safer chemicals, safer auxiliaries and solvents, design with energy efficiency, use of renewable feedstocks, reduction derivatives, selective catalytic reagents perform better than stoichiometric reagents, design for degradation, real-time analysis for pollution prevention, and accident prevention (ACS Green Chemistry Institute, 2021). These principles are being taught and applied in chemistry education in universities to answer the challenges of today's world (Armstrong et al., 2019; Mulyanti et al., 2022; Srivastava & Sharma, 2021).

Regardless of the implementation method, educators need an effective and rapid strategy to assess students' knowledge of GC principles. One of the instruments that have been prepared is the ASK-GCP (Grieger et al., 2022). This instrument assesses students' knowledge of GC. The reliability and validity of the instrument were very good. Knowledge of this principle needs to be tested on the pre-service teacher so that educators know the extent of their understanding of GC. Chemistry education has a central role in education for sustainable development, especially sustainably (Burmeister & Eilks, 2013). The process of planting the principle starting with prospective chemistry teachers who will go down directly to become chemistry teachers (Loste et al., 2020).

Previous research investigated knowledge, perceptions, and level of integration GC from teachers in Senior High School (Carangue et al., 2021). Instructors recognize the importance of GC in the curriculum. Instructors have also made efforts to socialize GC. However, the extent of its integration is only the beginning of an in-depth and proactive pedagogical approach that aims to highlight sustainability practices. GC is not only applied but its implementation must be evaluated (Carangue et al., 2021). It is necessary to assess the GC pre-service teacher because they will play a role in implementing GC in the college.

Educational assessment is very important to improve the teaching and learning process in college (Gao et al., 2020). Because without an educational assessment it will be difficult to know for sure whether the learning progress that has been achieved or not (Cooper & Stowe, 2018). The results of this analysis can help educators to be more effective in designing further learning. Through the analysis of student knowledge, it will be possible to identify students who have a high level of knowledge on understanding GC. The results of this study are also expected to be the basis for decision making at higher levels. This study focuses on measuring the knowledge of the pre-service chemistry teachers about the principles of GC.

Method

This research is a survey research to analysis the GC knowledge of pre-service teacher. The research was carried out in UIN Walisongo Semarang, Indonesia. Respondents involved in this study came from the pre-service teacher at Chemistry Education Progam. The total sample is 90 students consisting of 16 students from class 2018 (Code A), 16 students from class 2020 (Code B), 24 students from class 2021 (Code C), and 36 students from class 2021 (Code D).

Students' knowledge of GC principles was tested with ASK-GCP (Grieger et al., 2022). ASK-GCP consists of 24 questions in multiple true-false formats. Taking into account the lecture conditions, the questions were converted into online questions by utilizing the Google Form platform. The online questions link was distributed to the respondents of Chemistry Education students. Table 1 presents six sample items from ASK-GCP.

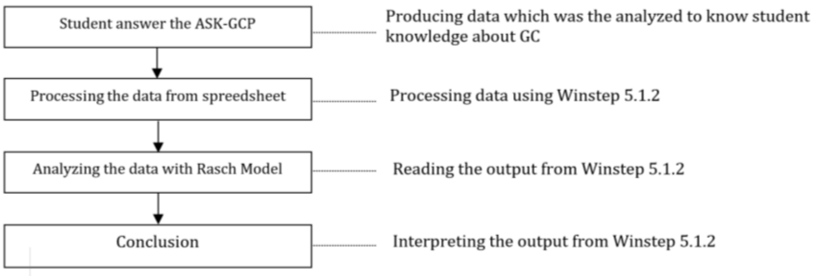
Table 1
Examples of Items in ASK-GCP

Item Code	Statement	Answer		
		True	False	Don't know
Q1	Knowledge of environmental chemistry and toxicology plays a role in designing safer chemicals.			
Q5	When synthesizing compounds, the raw elements' relative toxicity should be considered.			
Q12	The optimal ratio of mole ratio of reactant and catalyst is 1: 1			
Q16	Analytical method when reaction progress monitoring is used to measure yield			
Q20	Chemicals with a high reactivity will only react with their designated targets, not other biological and ecological targets.			
Q24	Chlorine is quickly metabolized in organic molecules.			

The collected data is analyzed by Winsteps 5.1.2. with Rasch Model. The Rasch model does not depend on the sample used, which is one of the features of the Rasch model. The Rasch model can sort the questions in a structured manner from the most difficult to the easiest and the respondents from the highest to the lowest ability. Besides that, any inconsistency in the answers of the respondents (misfit) or unusual patterns (outliers) will be detected. The correct answer is given a rating of 1, and the incorrect answer is given a rating of 0. When the respondent answered the "don't know" option in the answer choices, the answers were grouped as wrong answers because it showed that the respondent didn't know the information asked.

The level of knowledge of the principles of GC can be known through the acquisition of a logit score based on the Person Measure table (Sumintono & Widhiarso, 2015). In the person measure table, information on the logit value of each student is obtained. The maximum logit value shows an excessive stage of student ability. Student abilities can be analyzed on the outliers or misfits on each item. In addition, we can see the distribution of differences in the ability to read and interpret student charts from the Wright Map item person (Sumintono & Widhiarso, 2015). The Wright map in the Rasch model was used to analyze the interaction between person logit and item logit. Instructors can identify individual student abilities and analyze the quality of the questions. In addition, the instructor can find out about the number of questions students cannot answer. The stages of the analysis are shown in Figure 1.

Figure 1
Analysis Stages

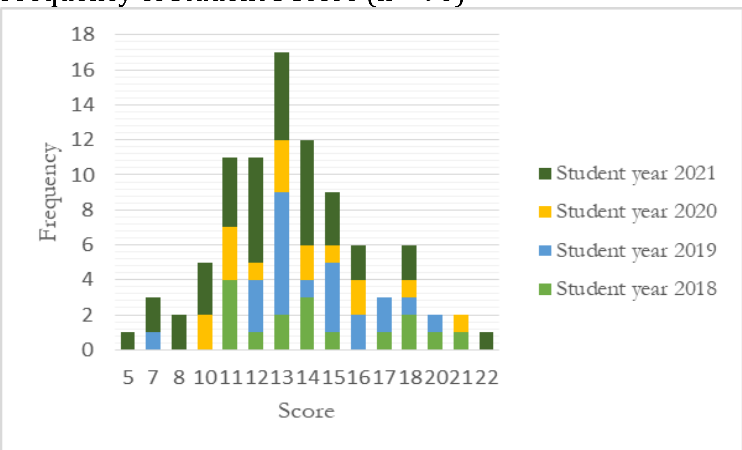


Result and Discussion

The type of research used is Educational Design Research. Teaching materials in the form of electrolyte and nonelectrolyte solution e-modules for ten grades of senior high school. In addition, an assessment is also carried out for the level of validity, practicality, and effectiveness of the resulting e-modules.

The descriptive statistics are calculated for each group by year and are shown in Table 1. The possible scores range from 0 to 24. The average student's score for class 2018 is 14.56, for class 2019 students is 14.18, for class 2020 is 13.62 and for class 2021 is 12.30. Students in class 2018 have the highest average because they have studied chemistry for four years. Distribution of student score and frequency show in Figure 2.

Figure 2
Frequency of student's score (n = 90)



This study explains how the Wright map mostly represents student understanding of. Table 2 displays the logit value (measure) for person and item. The logit value shows the ability's students to handle ASK-GCP questions. The logit value corresponds to the entire score stating the number of correct answers. For example, the respondent who obtained the highest logit was 2.75 (14A). This student was able to correctly solve 21 of the 24 questions given (see total score max). When compared with students with code 71D, who had a value of -2.01 logit, 5 out of 24 questions were correct. Table 2 shows the data from the analysis of the measured person and items.

The person reliability value (0.57), it means that the consistency of student answers is weak. Then the item reliability value (0.96), means that the quality of the test items is good category. Cronbach's Alpha is 0.58 with an adequate category, meaning there's sufficient interaction between individuals. This is influenced by the number of questions and the relatively small number of respondents in a test sample of questions (Sumintono & Widhiarso, 2015).

Based on Table 2, the mean person logit is 0,43. The mean person logit is greater than the item logit (0.00). That indicates a tendency for higher ability than the difficulty level of the questions. The highest person logit is 2.75, and the highest item logit is 2.66. At the same time, the lowest person values and item logit are -2.01 and -2.94. The value of separation measured person shows 1.15, so the value of H is 1.87. This means that there are two grades of students, namely low and high.

Table 2

The Output of the Analysis of the Measured Person and the Measured Item.

	Person	Item
N	90	24
Measure (logit)		
Mean	0,43	0,00
SD (standard deviation)	0,85	1,68
SE (standar error)	0,09	0,34
Max	2,75	2,66
Min	-2,01	-2,94
Outfit mean-square		
Mean	0,98	0,98
SD	0,58	0,28
Reliability	0,57	0,96
Separation	1,15	5,20
Alpha Cronbach	0,58	

Item Fit and Logit of ASK-GCP

The fit statistics analysis with the Rasch Model can provide information to researchers whether the data ideally depicts that people with high abilities provide patterns of answers to items according to their difficulty level. From Table, the most difficult item is Q16, and the easiest is Q1. Items that behave consistently with what is expected by the model mean that the items fit. Indications that students have misconceptions about the items are found if the questions do not fit. Outfit means-square (MNSQ), outfit z-standard (ZSTD), and point measure correlation (Pt Measure Corr.) as an indicator of item suitability are some of the fit indices provided in the Rasch analysis. Item fit and logit are show in Table 3.

In the table above, it can be seen that the topmost item, namely Q16, has a tendency not to fit. Q16 asked about "Analytical method when reaction progress monitoring is used to measure yield". When viewed from the three aspects, Q16 items are not eligible for Outfit MNSQ (2.03) and ZSTD (2.36) and point measure Correlation (0.01).

Table 3
Item Fit and Logit

Item	Measure (logit)	Outfit		PT. MEA Corr.	Criteria
		MNQS	ZSTD		
Q1	-2.94	0.80	-0.08	0.17	Fit
Q2	2.01	0.99	0.02	0.29	Fit
Q3	0.63	0.95	-0.47	0.39	Fit
Q4	-0.14	0.96	-0.26	0.40	Fit
Q5	-2.32	0.45	-1.27	0.44	Fit
Q6	-2.32	0.62	-0.76	0.38	Fit
Q7	-0.14	1.03	0.25	0.29	Fit
Q8	-0.48	0.82	-1.18	0.47	Fit
Q9	0.43	0.90	-1.00	0.42	Fit
Q10	0.68	1.02	0.23	0.36	Fit
Q11	-2.7	0.94	0.10	0.12	Fit
Q12	2.09	0.80	-0.76	0.42	Fit
Q13	-1.22	1.03	0.20	0.21	Fit
Q14	-1.14	0.94	-0.15	0.29	Fit
Q15	1.93	0.91	-0.32	0.38	Fit
Q16	2.66	2.03	2.36	0.01	missfit
Q17	1.58	1.08	0.50	0.22	Fit
Q18	0.79	1.20	1.77	0.19	Fit
Q19	-1.67	1.28	0.87	0.14	Fit
Q20	1.34	1.09	0.60	0.23	Fit
Q21	1.4	1.09	0.61	0.26	Fit
Q22	-0.6	0.93	-0.37	0.34	Fit
Q23	-1.38	0.80	-0.62	0.37	Fit
Q24	1.52	0.80	-1.18	0.50	Fit

Therefore, the Q16 items cannot measure students' knowledge related to GC. For the other items, only does not meet one criterion, so that the conclusions of the 23 questions can be understood well by students, and one question (Q16) has a misconception.

Students' ability to answer questions can be determined using Winsteps 4.6.1 software on the output Wright maps, a menu that also displays the level of difficulty of the questions analyzed by the Rasch Model. The results of the output Wright map can be seen in Figure 3. Wright map is split into two spaces: left and right. On the left side is the distribution of the person's ability, while on the right side is the distribution of items (questions). Items that have the highest difficulty level are at the top, while the easiest items are at the bottom.

Based on the Wright Map, item Q16 is a question with the highest difficulty (2.66 logit), meaning that the probability of all students correctly doing this problem is very small. Question Q1 is the question with the lowest logit (-2.94 logit). In this case, almost all students can solve this problem correctly. Through wright maps and measure order data, four students with logit more than +2, namely students with code 14A, 17A, 05A, and 18B. These are different levels of ability or intelligence (outlier). The one students with the lowest logit (71D;-2/01) were categorized as very low ability (outliers because they were outside the T limit).

Wright Map Analysis

For students 14A, almost all of the questions can be solved correctly except for questions Q17 and Q16. However, these questions should be answered because 14A (2.77 logit) is higher than the item logit for Q17 (1.58 logit). The student's logit value is higher than the item logit, meaning that the probability for the student to correctly answer the question is more than 50%. Two students with the same logit 05A and 18B (2.34 logit) were compared to a question with almost the same logit, namely question Q4 (-0.14 logit), and the probability of the two students working on Q4 correctly was 50%. Among the three students, only 05A students answered correctly.

The analysis of the comparison of logit person and logit response items based on the map variable map shows that the logit person is much higher than the logit item response. This shows that the overall respondent's ability is higher than the difficulty level of the response items. This is indicated by almost all respondents agreeing to all aspects of the response items given.

The analyses based on the Wright Map provide valuable information for educators to identify student abilities. At the same time, you can analyze the questions being tested. Because the logit scale on the Wright Map has the same interval, accurate information can be obtained, for example on questions where students fail, so that corrective efforts can be made. Likewise, education can easily find out which questions students managed to do correctly.

Figure 3
Wright Map

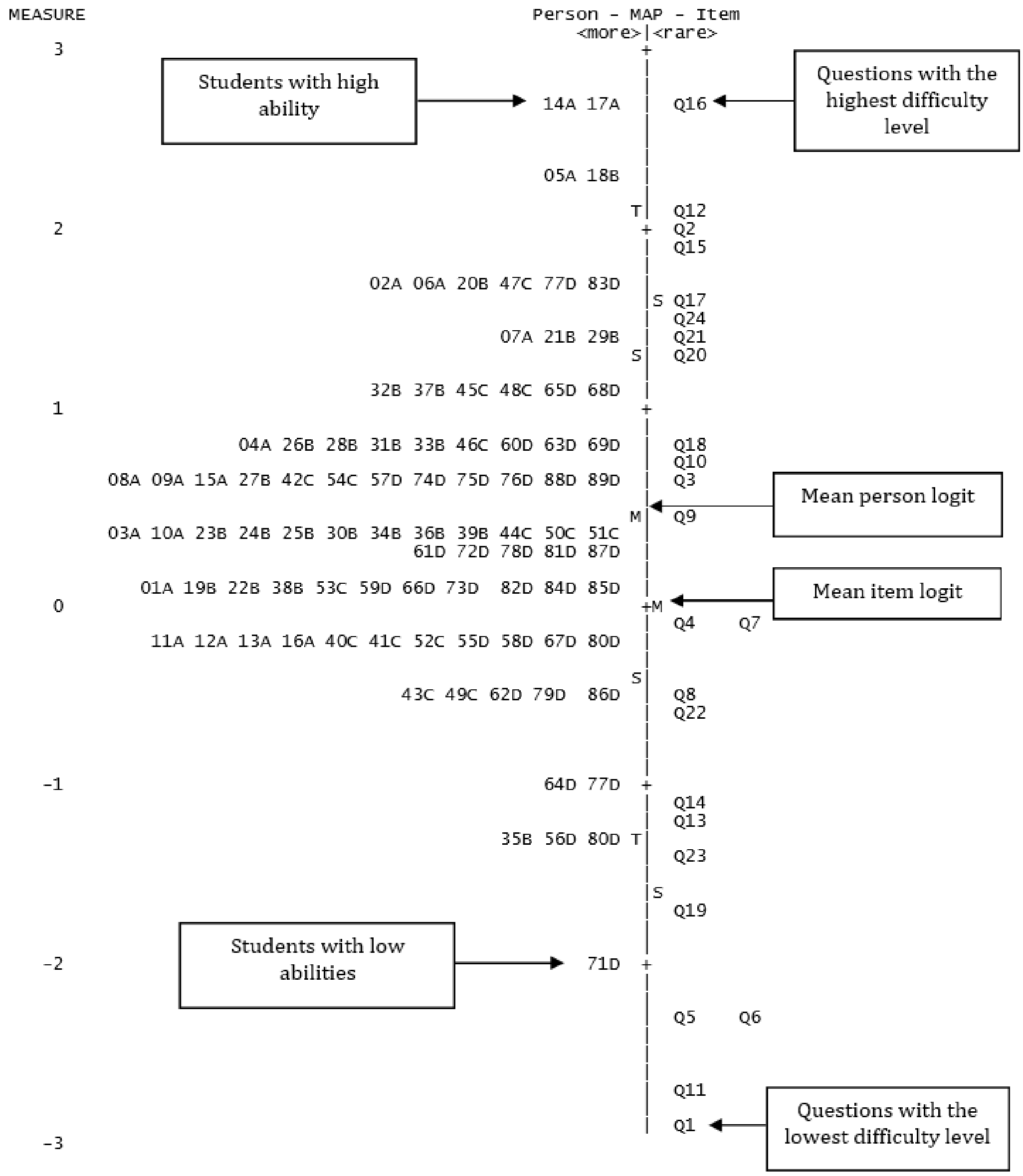


Figure 4
Scalogram

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    GUTTMAN SCALOGRAM OF RESPONSES:

 Person |Item
        | 1  12112      1122211 11  ID    logit
        |11569334284793080147522 6  Person       Person
        |------------------------
     14 +111111111111111111101010  14A    2.75   } the pattern of student answers with
     17 +111111111111111011110111 0 17A    2.75   } the highest scores

     18 +111111111111111101110100  18B    2.34

      5 +111111111101111101101011  05A    2.34   } careless and guessing answer
     20 +111101111110111111110000  20B    1.68   }
      7 +111101111011100001110111  07A    1.39   }
     50 +101111110101000011000101  50C    0.32   }
     64 +011111000001000100000001  64D   -1.04   }
        |------------------------
        | 1  12112      1122211 11
        |115693342847930801475226
```

Information on the response pattern can be further identified by looking at the scalogram in Figure 4. Rasch model analysis by compiling a Guttman Matrix or scalogram is one way to facilitate understanding of the principle. Each item that will be sorted according to the level of difficulty is a characteristic of a Rasch model. This Guttman matrix aims to make it easier to analyze, predict, and provide explanations that simultaneously predict individual abilities and the level of difficulty of each item. The left and right sides show the identity of the person and the top side shows the order of easiest to hardest questions from left to right. The analysis on the scalogram makes it easier for teacher to find out the reasons why some students give response patterns (how to take the exam) that are not following the model. As in students 05A, 20B, 07A, 50C and 64D. These students can be categorized as inaccurate because they are not able to answer relatively easy questions.

Based on the calculation of the separation of persons, there are two categories of person abilities, namely high abilities and low abilities. We can count the number of students with high categories through the Wright map. 44.5% of students (40 out of 90 students) in the high category of knowledge about GC. However, 55.5% of students are low knowledge about GC. Several factors are the cause, students do not know about the concept of green chemistry. Seen in students class 2020. This is because student class 2020 have not received courses about green chemistry. They only know from chemistry laboratory work. The development of green chemistry-based chemistry is urgently needed in the chemistry field, including chemistry education. In addition to interacting with chemical substances, chemistry education also interacts with prospective teacher students (Taha et al., 2019). The inculcation of safe chemistry concepts will continue to students . The concept of uncontrolled use of chemical substances will cause environmental damage. The low initial ability of environmental chemistry students affects the objectives of the Chemistry Education study program. GC is an approach to preventing environmental pollution due to chemicals. Therefore, the concept of GC needs to be applied in university chemistry learning (Gross, 2013).

Several areas require further emphasis to advance the strategic area with GC namely depolymerization and defunctionalization methods for existing chemicals that enable circularity. Circular system design considering human health and harmless chemicals. Implementation of machine learning and big-data methods (Ganesh et al., 2021; Zimmerman et al., 2020; Zuin et al., 2021)

The GC concept aims to reduce pollution caused by chemical processes and products that can interfere with environmental quality (Chen et al., 2020). The GC approach in laboratory activities can be developed and applied, among others, by replacing raw materials in the manufacture of chemical compounds, replacing safer solvents, replacing supporting materials in a chemical process, and minimizing the dangers of practical waste or processing waste. Chemistry learning can be done in the classroom or in the laboratory (Zuin et al., 2021). Chemistry learning in the laboratory in the form of a green chemistry-based practicum will increase students' sensitivity to the environment (Hamidah et al., 2017). Environmental sensitivity will increase students' creativity in designing independent practicums based on green chemistry (Chen et al., 2020).

Conclusion

The result of describing the interaction between the person and the item on Wright map shows that almost all students can answer the ASK-GCP. However, a tiny low range of students with low student knowledge would like special attention from the teacher or instructor. This ASK-GCP survey can be used as a reflection of the importance of GC as an approach to preventing pollution due to chemicals that can damage the environment. The concept of GC needs to be applied in learning chemistry in schools and universities, especially in practical activities in the laboratory. The implication of this research is that there is further research on how to design learning activities, modules and strategies that can be applied in learning chemistry in the Chemistry Education study program at UIN Walisongo Semarang. This is very necessary to answer the challenges of today and in the future.

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