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Development of Standard Assessment for Understanding Green Chemistry Principles Based on Unity of Science

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Abstract

Understanding green chemistry is a crucial aspect for chemistry teacher graduates, as it equips them with the knowledge and skills to promote sustainable practices, minimize environmental impact, and inspire the next generation of students to engage in eco-friendly scientific innovation. This research is dedicated to developing a standard assessment for understanding Green Chemistry based on the Unity of Science (UoS), which is grouped into three categories: reagents, reaction processes, and reaction products. The research uses a mixed methods design with a triangulation model. A significant part of the research process is the validation of the feasibility of the instrument developed, which was done by five chemical experts. The multi-rater responses obtained were then analyzed using the feasibility criteria of the processed Rasch results. In the trial process, 40 students from the Chemistry Education program were selected as research subjects. The results showed that the reliability of the questions was 0.87, with an item separation level of 2.54. This reliability value of 0.87 indicates that the developed questions are of excellent quality and can be used as a standard for measuring understanding of Green Chemistry based on Unity of Science.

Keywords*:* green chemistry, rasch model, standard assessment, unity of sciences

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1. Introduction

The Green Chemistry concept which is based on twelve principles, aims to reduce or eliminate hazardous materials from the synthesis, production and application of chemical products. As a result, the use of materials that are harmful to human health and the environment must be reduced or eliminated (Mohammed & Errayes, 2020). Green chemistry was summarized by Anastas (2014) into twelve principles (Ivankovi, 2017) including: 1) prevention of waste formation; 2) atomic economy; 3) harmless chemical synthesis; 4) designing safer chemicals; 5) safer solvents and reaction aids; 6) design for energy efficiency; 7) use of renewable raw materials, 8) reducing derivatives; 9) safe catalyst; 10) design for degradation, 11) real-time pollution prevention and 12) inherently safer chemicals for accident prevention. So far, green chemistry principles have been realized in practical activities (Cosio et al., 2020; Wallen et al., 2020) and are rarely implemented in theoretical learning activities. It also measures student understanding, especially when integrated with religious aspects.

Green chemistry is a new paradigm in chemistry education, as chemists try to maintain sustainability (Aubrecht et al., 2019; Eissen, 2012). Sustainability is the focus of attention in all areas of life, including

education. As one of the study programs, chemistry education plays a role in graduating prospective chemistry teachers, as the primary contributor to realizing green chemistry in every learning activity. Green chemistry has been implemented from the beginning of lecture activities to students' final assignments, especially in the chemistry education study program at the Faculty of Science and Technology UIN Walisongo Semarang (Chamidah & Mulyanti, 2021; Hawa & Mulyanti, 2021; Widayanti & Mulyanti, 2021).

Another requirement for prospective chemistry teacher graduates is an understanding of integrating religious knowledge with the chemistry they have studied (Mustopo, 2017). This is undoubtedly a challenge for prospective chemical education graduates at PTAI to master the integration of the two. In the end, prospective chemistry teachers from PTAI (Islamic religious college) will become pioneers in teaching chemistry in schools. Chemistry learning that is integrated with Islamic values provides a comprehensive learning experience for students, where students not only learn chemistry but also understand its implications from aspects of understanding religion, which is the knowledge of the Koran (Mannan, 2018; Sarjuni, 2018; Zain & Vebrianto, 2017).

The Qur'an, as a source of knowledge for Muslims, is *a qauliyah* proposition that must be able to be interpreted, both in terms of interpretation and explanation in the fields of science. Another thing that is no less important is understanding the Qur'an's teachings as a reference in reading *kauniyah* verses that appear in all aspects of life. One aspect of life that is currently of primary concern is maintaining sustainability. Green chemistry, summarized in twelve principles (Anastas et al., 2014), is proof of the implementation of God's teachings, which are stated in every verse. The first verse in the Qur'an is a form of education and guidance from Allah so that humans can become a loving and merciful community, of course, with everything in their lives, one of which is towards nature.

Lafadz Basmallah, according to sufism experts, means the letter *ba'*, by asking for Allah's guidance and help *"I say and do"*. Second, i dedicate all this activity and creativity to Allah, not to expect remuneration from other people in the form of wealth or verbal praise; "*I don't even want thanks"*. Lastly, be with Allah in my silence and movement, my busy time, my free time, and my life and death.

The word *Ism* means name. A name is a sign given to something so it can be easily distinguished from something else. Names have two functions; if they relate to a figure, we admire them and hope to emulate them to the best of our ability. Meanwhile, if it is related to the name used as the name of a place, it means that we want the name always to be remembered or eternal. Based on these two functions, the series of sentences "*In the name of Allah*" contains two meanings, first by sincerely connecting every twenty-four hours of our life with the opportunity always to be guided by the Eternal Allah to be able to contribute and be creative for humanity and serve God. This is done by hoping for God's face. Hopefully, it will be eternal in the afterlife, in the sense of receiving reward, forgiveness, and the blessing of Allah SWT. Secondly, the series of sentences, " *In the Name of Allah, the Most Gracious, the Most Merciful*," means that we should emulate the two characteristics of Allah SWT, they are *Ar-Rahman* and *Ar-Raheim,* according to our abilities and abilities in saying and doing things.

By emulating the characteristics of *Ar-Rahman* and *Ar-Raheim*, we hope that what we say is of proper quality based on knowledge and not contaminated by lies and hypocrisy (*Qaulan Syadida*) and that our words are always gentle and easily resonate in the heart without neglecting firmness (*Qaulan Layyina*). These two characteristics of our words are used to remind us of the truth based on sharp thinking and clarity of heart

and to remind us always to maintain patience, both patience when facing disaster and sorrow, patience so that oneself does not fall into the humiliation of disobedience, and patience so that one does not forget oneself. I don't know myself when I am blessed with various pleasures. Apart from that, we also hope to emulate the characteristics of *Ar-Rahman* and *Ar-Raheim*. What we do is the best practice, which is valuable to humans and labeled as a blessing for the universe.

Green chemistry principles, which are based on verses from the Qur'an, is an embodiment of the unity of knowledge that students should master as preparation for becoming chemistry teachers in the future. In this research, researchers grouped the twelve principles of green chemistry into three parts; 1) reactants; 2) reaction processes and 3) reaction products. The following four components are extracted from each verse of the Qur'an, which will be used as a reference. One of Allah's attributes is *Al Khaliq*, the Creator. According to chemistry, creation creates a new compound from an initial compound as a reactant. This is the primary basis because every verse of the Qur'an is a realization of Allah's knowledge, which must continue to be studied and realized so that it is beneficial for human benefit.

2. Research Method

The research used a mixed methods design (Cohen et al., 2018) with a triangulation model (Bandur, 2019). Mixed methods are implemented, starting from the research framework, data collection, and data processing to interpreting research findings.

2.1. Research Stages

The stages of this research include: 1) green chemistry principles based on the unity of science; 2) preparation of assessment items; 3) consultation on the contents of the assessment with experts (in the fields of religion and chemistry); 4) Feasibility assessment survey for experts (chemistry).

2.2. Research Subject

The subjects in this research included five experts in the field of chemistry who also understand the religious aspects of chemical concepts, as well as three experts in the field of Al-Qur'an who understand the field of science. The selection of experts as raters or validators is done by conducting interviews and reviewing the work these experts have produced. In the trial process, the research subjects selected were 40 students from the Chemistry Education study program at one of the State Islamic Universities in Central Java. The subject was chosen with consideration, having mastered chemical concepts and religious material sufficiently during his three years as a Chemistry Education student at one of the Islamic Universities.

2.3. Research Instrument

The research instrument is a response questionnaire to the items developed (Cohen et al ., 2018). The research instrument aims to obtain research data, which is the feasibility of the assessment developed through expert responses in the form of open comments and the evaluation of the subjects selected during the limited trial.

2.4. Data Analysis

2.4.1. Quantitative Data

The expert response survey was analyzed quantitatively using the Facet program to determine the results of the expert responses. If the consistency of the raters is known based on statistical standards from the Rasch Model, then a review of the results of the raters' responses is carried out.

Instrument feasibility analysis based on the Rasch model. The study aims to determine the quality of the assessments developed and assessed by the raters. The analysis includes the quality level of the questions based on the Whright map of the logit values obtained from each question item. Next, the feasibility of the assessment is determined based on the statistical criteria of the Rasch model.

Validation was obtained from the experts' responses, looking at the consistent pattern of expert answers through the data processing results using the Rasch model in the Facet program. The obtained multi-rater responses are then analyzed using the feasibility criteria of the processed Rasch results (Boone, 2016).

2.4.2. Qualitative Data

Suggestions or input from expert validators were analyzed qualitatively using NVivo Pro 12 software. Suggestions or input from experts are then coded through the nodes on the NVivo map. Comments are open-ended, so the researcher will code based on the findings from when the research was conducted.

3. Result and Discussion

Chemistry is a field of knowledge and essential science in the development sector industry and technology has also become the foundation for producing lots of products. Before it can be used for a product, substance chemistry must synthesize and purified, moreover formerly, through a number of procedures in energy processes as well as mixing with substances and other chemicals at an atomic level or molecule. From these various processes, perhaps contamination material chemistry to the environment, good during the synthesis process, or afterward (waste resulting reaction).

We realized that we cannot change characteristic material chemistry in condition specific. However, we can minimize the effect of the side that is not desired by making something the right decision. For example, the material amount of chemicals is calculated to produce a product specific and not excessive. To handle that matter, then appear something known as the concept of "green chemistry" where in conducting chemical synthesis, attempts to use energy efficiency and the proper technique to remove it or reduce waste toxic as well as a its bad consequence such as accidents and dangerous chemicals, living creatures and the environment (Zuin et al., 2021).

Scientists in chemistry keep investigating the road to realizing the number of great products. However, with way more efficiency, quantity, minimal waste, no bother to the health of humans and the environment over two decades, green chemistry is getting better developed in a way that is broad in a variety of community scientific fields throughout the country.

Drafting green chemistry becomes an exciting idea for continuing the development of knowledge with way more sustainability (Ardila-Fierro & Hernández, 2021). Green chemistry began to become popular when it was felt that sustainability programs still did not accommodate various aspects of chemical research, which had so far contributed significantly to the impact of environmental pollution.

The green chemistry design carries an eco-friendly principle with a method of minimizing the use of chemicals, which is dangerous and can threaten the health of living creatures and the environment, including hazardous toxicity, physical danger, and so on. The green chemistry process covers almost all parts of chemistry, such as inorganic, organic, biochemical, polymer, environmental and toxicology chemistry. Through several applicable green program trends such as catalysis, bio-catalysis and the use of safe alternatives: renewable raw materials (biomass), reaction solutions (such as water, ionic fluids and supercritical fluids), reaction conditions (microwave irradiation) and new synthetic pathways (photocatalytic reaction), the purpose of environmental protection and economic benefits can be achieved. This poses a challenge for innovators to design and utilize materials and possible energy that are possible to improve performance while protecting health, human living, and the environment (Silvestri et al., 2021). Various studies that apply the principles of green chemistry have been developed, ranging from laboratory research

to learning activities (Chen et al., 2020; Lee et al., 2014). Basically, experiments that apply the principles of green chemistry are experiments that use environmentally friendly materials and low concentrations; the procedures for carrying out experiments are safe and do not produce dangerous by-products in the form of waste. For the environment and health (Wahyuningsih & Rohmah, 2020).

Green chemistry makes tons of contributions, including in the development and implementation of new technology in various fields of knowledge. Innovative technology and "green" thinking can become a road for facing increasingly global challenges, especially during walking time. Green chemistry is also a contributor to the implementation of sustainable education (Burmeister et al., 2013; Eilks, 2015; Sinakou et al., 2019). Various types of strategies and point focus. There is a time to implement green chemistry design in science education. Either in terms of theory or practice. This matter is done to provide education to students that science, especially chemistry, contributes to development. However, there is no standard measurement for how to determine students' understanding of the principles of green chemistry, especially the specifics of each principle.

3.1. Quantitative Data

3.1.1. Feasibility of the Developed Assessment

An essential consideration in the Rasch framework is "fit" as the quality control mechanism, fit evaluates how well the obtained data fits the Rasch model. If the data deviate significantly from the Rasch model, the cause needs to be considered, and individuals or items that do not fit may or may not be removed. It is helpful to consider Rasch's "goodness of fit" analysis to investigate whether an instrument's items involve a single trait and if individual responses provide a confident calculation and communication of one's measurements along a single trait. Two statistics that can be used to assess fit are infit (inlier-sensitive or information-weighted fit), and outfit (outlier-sensitive fit) (Linacre, 2002). For the introductory analysis we present, clothing will be used.

Fit statistics are generally reported in mean squared (MNSQ) and z-standardized (ZSTD). MNSQ is the average of the squared residuals for an item (Bond & Fox, 2019). In contrast, ZSTD, the standard form, transforms mean squared values with sample size correction (Bond & Fox, 2019). Additionally, ZSTD relies on sample size; MNSQ is sample size independent when the noise in the data is spread evenly across the population (Linacre, 2002). Considering the different types and forms of goodness-of-fit statistics, which one should be used to evaluate mismatches. Although various recommendations have been presented, Boone et al. (2016) and others recommend checking MNSQ clothing first. MNSQ scores of less than 1.4 are acceptable for rating scale data, and scores of less than 1.3 are acceptable for non-high-stakes multiple-choice tests (Boone & Scantlebury, 2006).

3.1.2. Feasibility of Question Items from the Reliability Aspect

Reliability is the consistency of the respondent's answer pattern to the questions. If the difficulty level of the questions is in line with the student's ability to answer the questions, then good reliability will be seen. In Figure 1, the reliability of the items is 0.87, with an item separation level of 2.54. The reliability value of 0.87 shows that the questions developed are outstanding (Boone & Noltemeyer, 2017). Likewise, the level of question separation is considered good, with a value of 2.54 (Laliyo et al., 2020).

SUMMARY OF 25 MEASURED Item

	TOTAL SCORE	COUNT	MEASURE	MODEL ERROR	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	126.3	42.0	.00	.20	1.15	-.2	1.10	-.3
S.D.	21.8	.0	.78	.08	.70	2.9	.55	2.7
MAX.	164.0	42.0	1.13	.50	3.88	3.3	2.88	3.1
MIN.	84.0	42.0	-2.19	.15	.12	-7.9	.12	-7.5
REAL RMSE	.29 TRUE SD		.73	SEPARATION 2.54	Item	RELIABILITY	.87	
MODEL RMSE	.21 TRUE SD		.76	SEPARATION 3.56	Item	RELIABILITY	.93	
S.E. OF Item MEAN = .16								

UMEAN=.0000 USCALE=1.0000
Item RAW SCORE-TO-MEASURE CORRELATION = -.95
1050 DATA POINTS. LOG-LIKELIHOOD CHI-SQUARE: 2335.19 with 981 d.f. p=.0000
Global Root-Mean-Square Residual (excluding extreme scores): .8961

Figure 1. Reliability of Question Items

3.1.3.Unidimensional

Another aspect that supports a test instrument that is suitable for use is its ability to measure the variable being measured, which can be seen from the uni-dimensional results of the from unexplained variance Rasch processing. Construct validity in modern statistical analysis through uni-dimensionality data. Uni-dimensionality analysis shows that the questions are not biased in measuring the expected variables, the value from analysis using the Rasch model shows that the raw variance data obtained is above 20%, and the value is below 15% (Davidowitz & Potgieter, 2016).

Uni-dimensionality is the number of common factors or latent constructs required to explain the correlation between variables. Therefore, factor analysis is an appropriate and popular method for assessing construct dimensions. One can use exploratory factor analysis (EFA), confirmatory factor analysis (CFA), or both to determine construct dimensions.

A set of items is considered unidimensional if a single common factor can explain the correlation between them. This conceptualization of uni-dimensionality is consistent with that proposed by McDonald. An item is considered unidimensional if it measures only one latent construct or factor. If some set of n items from a construct's domain is taken and the partial correlation between each set equals zero, then the construct is considered unidimensional. It is possible, however, that a set of items may be unidimensional, but individual constructs or indicators may not be unidimensional. The item set is unidimensional because one common factor explains the correlations among the items, and each item is unidimensional because it measures one and only one construct.

A review of the extant literature using confirmatory factor analysis (CFA), covariance structure modeling, or structural equation modeling (SEM) strongly suggests a preference for the use of unidimensional items and, in the context of specific research studies, strong loadings on a single (Netemeyer et al., 2003).

Although there has been no systematic investigation into why such items should be preferred, prima facie solid preferences appear historically based on using the sum score of items on a particular scale in ANOVA and regression-based analyses rather than individual items, even when personal items are used in covariance structure models (e.g., SEM), the tendency is to report statistics such as corrected item-to-total correlations and coefficient alpha, which are characteristics of, or involve, summed scores.

Table of STANDARDIZED RESIDUAL variance (in Eigenvalue units)

		-- Empirical --		Modeled
Total raw variance in observations	=	35.0	100.0%	100.0%
Raw variance explained by measures	=	10.0	28.5%	28.9%
Raw variance explained by persons	=	1.4	4.1%	4.1%
Raw Variance explained by items	=	8.5	24.4%	24.8%
Raw unexplained variance (total)	=	25.0	71.5%	100.0% 71.1%
Unexplned variance in 1st contrast	=	3.4	9.8%	13.7%
Unexplned variance in 2nd contrast	=	2.6	7.4%	10.3%
Unexplned variance in 3rd contrast	=	2.3	6.6%	9.3%
Unexplned variance in 4th contrast	=	2.2	6.3%	8.7%
Unexplned variance in 5th contrast	=	1.7	4.9%	6.8%

Figure 2. Uni-dimensionality of Items

Figure 2 shows that the value of Raw variance is 28.5 %, and the value of unexplained variance is 9.8%. So, the questions developed meet the unidimensional criteria of the Rasch model, the questions unitarily measure the expected dimensions.

3.2. Qualitative Data

This research was also assisted by NVivo 12 software in mapping the results. This is because NVivo can work transparently and efficiently in time and input various data types. Some are Word files, images, PDFs, videos, social media, and web pages. Data analysis was carried out using percentages and mapped with the help of NVivo 12 software.

NVivo was first introduced in Australia (Rasyid et al., 2022) and is widely used in qualitative research. This advantage can help

map research results so that researchers can draw conclusions from the results. NVivo 12 is based on the need to map the results of open questionnaires conducted with each participant. Thus, the results can provide an overview of the assessment being developed.

Suggestions or input obtained from expert validators were analyzed using the NVivo Pro 12 program (Bandur, 2019; Mulyanti et al., 2022). Analysis was carried out to get a connection between expert comments and the codification of question eligibility criteria. Analysis via NVivo Pro 12 is carried out through mapping or grouping validator comments. Grouping comments is divided into three criteria; 1) improvements and suggestions regarding the context of the questions and the content of the questions created; 2) corrections to the editorial command on the question; 3) context of religious aspects integrated into the questions

These three criteria become a reference in determining the labels or nodes listed on NVivo. Each node is divided into three child nodes according to criteria one and two. The first criterion consists of three child nodes: question description, relationship between indicators and questions and answer choices. The editorial criteria for questions include questions, writing reaction equations, and writing molecular formulas.

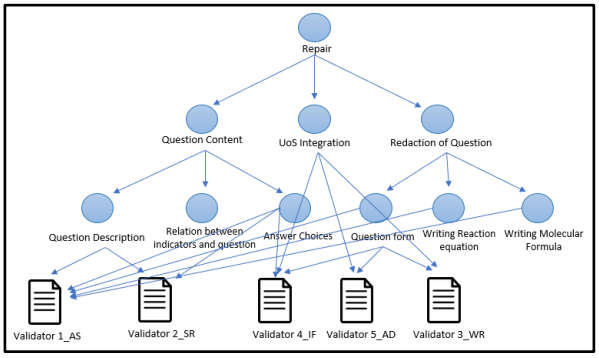

Figure 3. Mapping of Experts'Open Responses with Nvivo Pro 12

In Figure 3, the comments from experts indicate that improvements are needed in the question editing. Improvements to the question editor are because the questions are multiple-choice with polytomous assessment, so it is recommended that questions do not lead to just one answer.

4. Conclusion

A standard assessment instrument for understanding green chemistry has been developed based on a unified science of 27 items. The principles of green chemistry are grouped into reagents, methods, and reaction products. The questions are multiple-choice, with a score of one to four. After experts passed the validation stage, the number of questions was reduced to 25. The research results showed that the reliability of the questions was 0.87, with an item separation level of 2.54. The reliability value of 0.87 shows that the questions developed are excellent. The assessment questions that have been developed can be used as a standard for measuring understanding of Green Chemistry based on Unity of Science.

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