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Is the Creativity of First-Year Students in Stoichiometry Learning Affected by Their Chemistry Scholastic Ability?

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Abstract: This study aims to examine the correlation between scholastic ability in chemistry and creativity in stoichiometry learning among first-year students. Chemistry scholastic ability is naturally integrated among first-year students who demonstrate their reasoning skills in the field of chemistry, which may influence students' creativity in their chemistry learning. This quantitative research used a correlational design to examine two variables without providing an intervention. The research results showed a significant correlation between scholastic ability in chemistry and creativity, but were inconsistent across the two creativity measures (verbal assessment of creativity [VAC] and figural assessment of creativity [FAC]). Chemistry scholastic ability had a significant correlation with VAC. The first-year students identified had moderate-level reasoning ability, as evidenced by their difficulties transforming stoichiometry knowledge at the microscopic-symbolic level. Students' reasoning abilities encouraged the emergence of an original idea for molecular modeling using environmentally friendly materials (VAC). Even though they did not achieve high-level reasoning ability, they succeeded in creating a mind map (FAC) on stoichiometry by supporting digital literacy. Reasoning ability can foster creativity as one of the 21st-century skills, enabling students to directly contribute to preserving the environment by using molecular modeling materials. They also solve daily-life problems more easily by applying stoichiometry knowledge visualized in a mind map.

Keywords: *creativity; chemistry; scholastic ability; stoichiometry learning*

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INTRODUCTION

The characteristics of stoichiometric materials involve more procedural knowledge than conceptual knowledge, so they tend to be learned by memorizing calculation formulas and pose difficulties when the questions are transformed into stoichiometric equations. Students had difficulty solving stoichiometric problems involving the mole concept, balancing reactions, and identifying limiting reagents and excess reactants, due to a lack of understanding and participation in learning (Shadreck & Enunuwe, 2017). Learning difficulties can be reduced through student-centered learning, which can encourage students to learn and improve academic outcomes through positive interactions between students and teachers (Jacobs & Power, 2016; Kaput, 2018).

The role of higher education in producing students/generation is not only to provide excellent knowledge but also to instill the skills and attitudes needed in the world of work. In the society 5.0 era, the key role of education is to provide students with insight into information literacy, to be used in generating creative ideas to solve community problems (Hitachi-UTokyo Laboratory, 2020). The main objective of higher education is to hone students' abilities in creativity, problem-solving, and in learning how to learn (Kasmaienezhadfard et al., 2015). The global creativity index (GCI) for the education category in Indonesia ranks 115 (GCI, 2016), indicating room for improvement through the implementation of creativity-based learning. Creative thinking is needed to adapt to rapid change in a world full of complex challenges, so that the contributions of the younger generation can drive innovation that benefits society's development (OECD, 2019). The complex challenge that students and lecturers have successfully overcome, having utilized the sophistication of digital technology in the learning process several years ago in response to the Covid-19 pandemic. Digital literacy became a need for students to explore information/knowledge. However, the goal of education is not only the acquisition of knowledge but also the generation of creative ideas to solve problems in society. Tang et al. (2022) found that digital technology affected student creativity, increasing motivation, cognitive processing, and higher-order thinking skills. Students' active involvement in learning can reach it.

Creativity-based activities in stoichiometry learning can be designed by having students create mind maps and molecular models. Mind maps promote the reasoning process when students learn digital information by mapping knowledge in a meaningful way. The mind map showed how students understand the concepts. Molecular modeling promotes students' creativity by using everyday or waste materials, helping reduce global waste problems. Molecular modeling is a student's project for learning. Wijayati et al. (2019) concluded that learning activities that encourage students to produce projects can increase students' creativity and participation in learning by allowing them to present their projects. The success of creativity-based learning depends on the teacher's courage to take risks and to implement long-term learning that helps students generate creative ideas, even though educational demands are generally knowledge-oriented (Sahlberg, 2009).

The implementation of learning in the society 5.0 era cannot be separated from the use of technology, which has a dominant influence on students' creativity. Aguilar and Turmo (2019) concluded that technology (web, digital platforms, and social media) contains rich information as a tool for fostering students' creativity through active problem-solving experiences. When students explore information, they engage in a reasoning process to better understand it. Reasoning is involved in solving problems. Fasko (2006) summarized several previous studies indicating a correlation between creativity and reasoning, which is affected by factors in information processing, such as sensing, decision-making accuracy, memory, communication, and quantitative knowledge. Reasoning abilities have been naturally integrated into the first-year curriculum and are covered in the scholastic test (Schult et al., 2016), as one of the requirements for university admission.

The Scholastic Aptitude Test (SAT) is used to assess students' basic knowledge (reading, writing, and mathematics), problem-solving skills, and communication, and is divided into the SAT Reasoning Test and the SAT Subject Tests (Cohen & Swerdlik, 2009). In this study, the SAT for chemistry subjects on stoichiometry material. The scholastic ability of first-year students in chemistry reflects their natural talent for solving problems that involve verbal, numerical, and reasoning components. Students' scholastic ability in chemistry is thought to affect their creativity. This is supported by Lawrence et al. (2003), who stated that the SAT measures the reasoning ability required to achieve success in college and society.

Muhid et al. (2020) found a strong correlation between verbal and reasoning abilities and students' achievement across several subjects, suggesting that these abilities can serve as predictors of academic success. Jenkins (1992) stated that the SAT as a predictor of academic success has become a subject of considerable debate, with contradictory findings suggesting that scholastic aptitude slightly predicts academic performance in college. This is supported by research showing that scholastic aptitude can be improved through coaching (Slack, 1980; Becker, 1990), so that first-year students' low SAT scores can naturally increase as they gain experience solving complex chemistry problems. Although the influence of SAT scores on academic success in knowledge remains a matter of debate, it is important to examine the relationship between first-year students' scholastic ability in chemistry and their creativity. The verbal, numeric, and reasoning abilities were integrated into individual students; it is thought to contribute to their ability to make creative ideas from digital information.

METHODS

This research was carried out through stoichiometry learning on basic chemistry lectures in the odd semester. The research population consisted of 86 first-year students from the chemistry education study program, batch 2020, Universitas Negeri Surabaya. The cluster random sampling technique was used to select 56 first-year students as the research sample. The research design used a correlational quantitative method without manipulating variables (Cresswell, 2012). The data collected from this research were chemistry scholastic ability and creativity. Students' scholastic ability in chemistry was assessed through an essay test. Students' creativity was observed in the products they created (molecular models and mind maps).

The Chemistry scholastic ability instrument was developed by researchers based on basic chemistry e-books (Zumdahl & Zumdahl, 2010; Chang, 2013; McMurry & Fay, 2012) and several previous research findings. Scholastic ability involves numerical, verbal, and reasoning aspects (Schult et al., 2016; Cohen & Swerdlik, 2009). Chemistry scholastic ability was assessed based on the completeness of its components: (i) numeric (N); (ii) verbal and reasoning (VR); (iii) numeric, verbal, and reasoning (NVR). Its instrument on the stoichiometry topic has been validated and reviewed by two expert lecturers in the field of chemistry education, who concluded that it is suitable for measuring chemistry scholastic ability.

Creativity data are divided into two types: verbal assessment of creativity (VAC) and figural assessment of creativity (FAC). The VAC is obtained from a molecular modeling activity, with an assessment based on the creativity component developed by Torrance, which consists of fluency, flexibility, and originality (Kim, 2017). The FAC is obtained from the activity of making a stoichiometric mind map with an assessment referring to the component completeness of the mind map by Evrekli et al. (2010) which reflects the creativity component by Torrance: 1) resistance to premature closure (concept link); 2) originality (crosslink); 3) fluency (examples); 4) elaboration (relationships); and 5) abstractness of titles (picture, image, and figure) (Kim, 2017). The creativity instrument on stoichiometry has been validated and reviewed by two expert lecturers in the field of chemistry education, who concluded that it is suitable for measuring creativity.

Chemistry scholastic ability, VAC, and FAC data were analyzed descriptively (by component and overall) to determine mean and standard deviation, which were used to categorize high, moderate, and low. Chemistry scholastic ability on VAC and Chemistry scholastic ability on FAC were analyzed using nonparametric correlational statistics (Spearman's rho) because the results of the prerequisite test indicated the data were not normally distributed. The results indicate a significant value ($p < 0.05$), so there is a significant correlation between the two variables (Cresswell, 2012).

RESULT AND DISCUSSION

The combination of Chemistry scholastic ability components generates three types. The achievement for each type of chemistry scholastic ability is presented in Table 1.

Table 1. Mean Score of Chemistry Scholastic Ability

Type	M	SD	Students (%)		
			High	Moderate	Low
Numeric (N)	85.27	30.07	8.93	80.36	19.64
Verbal and Reasoning (VR)	87.95	27.79	0	75.00	25.00
Numeric, Verbal, and Reasoning (NVR)	59.12	24.68	10.71	58.93	30.36

Students achieved the lowest mean score in the NVR type, as evidenced by the highest percentage in the moderate and low categories. They have difficulty solving complex problems in NVR chemistry, scholastic type, and in stoichiometry. It requires students' reasoning to interpret the microscopic representation (number of particles) into a stoichiometric value, as a numeric aspect, from the chemical equation, which is written as a verbal aspect. Hafsah et al. (2014) found that students had problems with chemical representation and difficulties with stoichiometric calculations because they were often taught to solve problems algorithmically. This research also found that students easily solve stoichiometry problems that involve only numerical ability, without a microscopic representation.

Sunyono et al. (2015) found that students had difficulty transforming the submicroscopic representation of excess reactants into a form consistent with stoichiometric equations. The main finding of this research is that Student-1 had a low NVR type score and had difficulty transforming microscopic representations into symbolic representations and predicting the final microscopic representation of the final reaction, as presented in Figures 1 and 2.

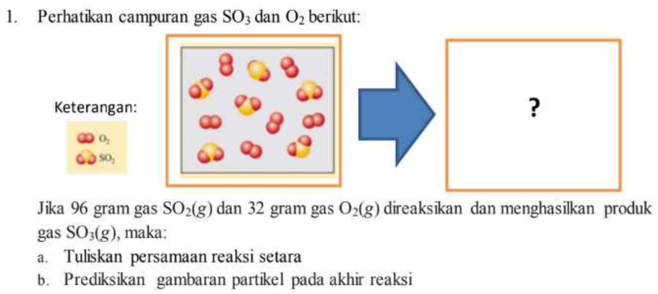

Figure 1. Chemistry scholastic instrument (NVR Type)

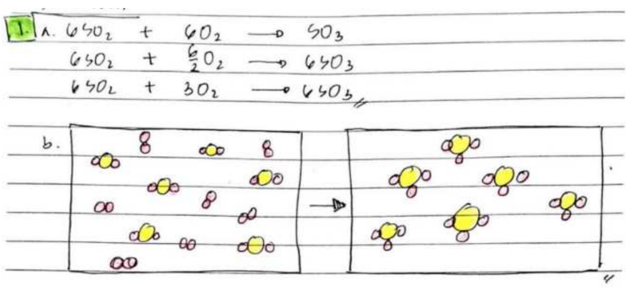

Figure 2. Student's difficulty answered the NVR type of chemistry scholastic ability

Students-1 have difficulty transforming the representation of reactant particles (6 molecules. SO_2 and six molecules O_2) in a balanced chemical reaction to produce SO_3. Students-1 tended to use numeric and verbal ability by directly balancing the SO_3 coefficient and changing the coefficient of the reactant O_2, namely $6SO_2 + 3O_2 \rightarrow 6SO_3$. Students-1 did not reason that the number of particles reflects the reaction coefficient; if the reactant coefficient is changed, it will violate the number of particles in the initial reaction. So that the correct way to transform the particle representation into a balanced chemistry reaction is to write $3O_2$ (the excess reactant to be found on the final reaction) on the proper side reaction to balance the number of O atoms as follows:

$6SO_2 + 6O_2 \rightarrow SO_3$ .... (i)
$6SO_2 + 6O_2 \rightarrow 6SO_3 + 3O_2$........(ii)
$6SO_2 + 3O_2 \rightarrow 6SO_3$.......... .....(iii)

So the net reaction (iii) is obtained as a balanced chemical reaction. Based on Figure 2, Student-1 had difficulty predicting the particle representation on the final reaction, which only described six SO_3 molecules. This is because it refers to the reaction equation, which was wrongly transformed by itself, so it does not consider the existence of excess reactant 3 O_2 molecules which are also found at the end of the reaction, which is symbolically written as equation (ii). Herga et al. (2016) concluded that the submicroscopic representation is the most difficult for students to understand because it is beyond the reach of experience (i.e., not observed). This shows that, even though first-year students have entered the formal operational stage of cognitive development, they still have difficulty thinking abstractly about chemical particles in stoichiometric equations.

The majority of first-year students achieved chemistry scholastic ability in VR and N type. They cannot solve complex chemistry scholastic problems involving NVR because they learned stoichiometry at the secondary school level, which often does not explicitly show the microscopic aspect. It just does stoichiometric calculations in balanced chemical equations as a symbolic aspect. This is supported by other relevant research. Salame et al. (2022) concluded that students have difficulty understanding the microscopic aspects of acid-base titration material, which is full of chemical calculations, so chemistry instruction should be designed to connect the three chemical representations (macroscopic, microscopic, and symbolic). The inability to understand microscopic phenomena can be scaffolded through visualization (Klerkx et al., 2013), such as using 2D or 3D molecular models. Then the lecturer will provide scaffolding for transforming the particle visualization into a stoichiometric calculation in a balanced chemical equation. Scholastic ability can be improved through a continuous coaching process (Becker, 1990). The interconnection of chemical representations can make students familiar with the reasoning process when they learn stoichiometry, so that they do not only memorize its formulas, which are full of procedural knowledge (chemical calculations). The reasoning process in stoichiometry learning is essential so that students can evaluate the scientific phenomena in the Martian movie, in which the astronaut experiences an explosion during a reaction to make water for potato fields to survive on the planet Mars after being left behind by windstorms. Hopefully, students can also use reasoning abilities to solve problems in the community, as an indicator of their readiness to face the society 5.0 era.

Creativity is one of the educational outputs expected to exist in students as the demands of the society 5.0 era (Kasmaienezhadfard et al., 2015; Yulianto, 2021). The rapid development of information and communication technology (ICT) is driving drastic changes in society and industry (Fukuyama, 2018), thereby encouraging the emergence of creative ideas among students. The types of creativity assessment carried out in this research are verbal assessment of creativity (VAC) and figural assessment of creativity (FAC), as follows:

VAC was evaluated through student activities that elicited prior knowledge of chemical bonds and valence shell electron repulsion (VSEPR), which were visualized using molecular modeling. This prior knowledge was elicited to promote understanding of how stoichiometry in a chemical equation involves the reorganization of atoms/molecules with specific molecular shapes. Sausan et al. (2020) concluded that Molymod can foster students' curiosity and motivation in learning molecular shape.

Molymod visualizes molecular shape, is made from plastic/wood, and is packaged in a media kit at a reasonably high cost. Molymod kits are widely used in schools/colleges in limited units, so they are implemented in class through demonstration. Okotubu (2020) concluded that the demonstration method affected students' academic achievement and retention of procedural knowledge (how to do something). However, the weakness of the demonstration method is that students cannot practice the procedure independently when the molymod is limited to a single unit, so they are prone to forget the exemplified procedure by the lecturer/teacher. First-year students must be given a chance to make molecular models using everyday materials that encourage creativity. The achievement of the mean score of the VAC component is presented in Table 2.

Table 2. Mean score of VAC in each component

Component	M	SD	Students (%)		
			High	Moderate	Low
Fluency	95.2	13.4	26.8	33.9	39.3
Flexibility	77.4	21.2	41.1	50.0	8.9
Originality	47.6	42.1	26.8	33.9	39.3

Based on Table 2, students' creativity tended to be evident in the components of fluency and flexibility, as it involves using materials from the surrounding environment, such as plasticine, toothpicks, and ice cream sticks, to make molymods. Students would explore knowledge through digital literacy when they made a molecular model. It helped students elicit bonding pairs, lone pairs, and bond angles that contribute to the molecular shape of the compound. Ritter et al. (2020) stated that the existence of Google can encourage individuals to use knowledge and generate creative ideas. In this research, the originality component of VAC was challenging to achieve because the majority of students modeled a single molecule with single bonds, without variations in double bonds, and without classifying it as an element or compound; however, students succeeded in visualizing the lone pair using two dots drawn on an ice cream stick. Figure 3 presents a sampling of VAC creativity.

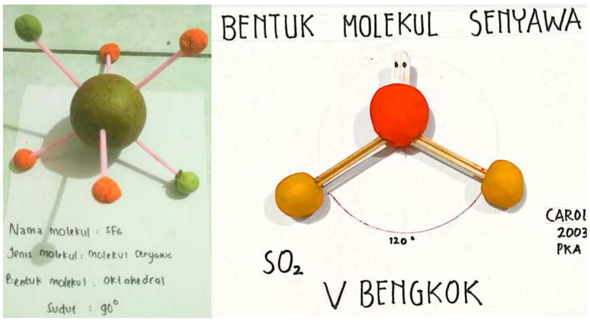

Figure 3. Sample of students' VAC creativity

Based on Figure 3, it is described that fig (a) student-2 reached category fluency (low), flexibility (high), and originality (moderate), while fig (b) student-3 reached category fluency (moderate), flexibility (high), and originality (moderate). Student-2 used flour dough and food coloring as well as plastic straws to make a molecular shape, while Student-3 used ice cream sticks to represent lone pair electrons on the central atom. Student-3 has been better at VAC than student-2. The findings of their innovations are not included in the assessment rubric, but for further research, they can be included in the originality category. Torrance described originality as a component of VAC as the ability of students to develop unlimited creative ideas and to always want to try new things, enriching intellectual life through literature (Kim, 2017). Acar et al. (2017) found that originality had the strongest correlation with creativity and innovation. When students used other materials to represent molecular shapes or did not exemplify the lecturer/teacher's materials (plasticine to represent atoms), it reflects their originality and creativity.

Flour dough, plastic straw, toothpick wood, and an ice cream stick were included as food waste. Students used waste materials for molecular modeling, which can help reduce environmental pollution. Students indirectly raised awareness of reusing/recycling food waste as a learning medium (Molymood) and not throwing it away into the environment. Manzoor et al. (2024) explained one strategy to reduce food waste: increasing public awareness of reuse or recycling to achieve Sustainable Development Goal 12 (SDG 12) on responsible consumption and production. Ortiz-de-Montellano et al. (2023) found that the circular economy has little effect on SDG 4 related to quality education. The circular economy, which focuses on value retention and regenerative practices of a product and has abandoned the traditional approach (take-use-dispose), has not been fully implemented in the field of education, so it is necessary to reuse/recycle waste materials in chemistry learning.

When students independently created molecular shapes and adjusted their creativity, it would encourage motivation in learning chemistry and make it easier to remember relevant prior knowledge. Bittermann et al. (2023) stated that prior knowledge is semantic in nature, facilitating direct memory encoding and making it easier for students to recall their knowledge when needed to solve problems. For example, students solved the phenomenon of a scientific movie "The Martian" about an astronaut who produced water through a reaction between oxygen gas ($O_2(g)$) and hydrogen gas ($H_2(g)$) which are its existence as molecules and not as free atoms. Molymood showed a visualization of the microscopic aspect of chemical reactions: the reorganization of molecules. It becomes more interactive and real for students, thus enabling them to achieve better academic outcomes (Yeboah et al., 2016). The majority of first-year students made molecular models that reflected the VAC components of fluency and flexibility in the high-moderate category, while originality was in the low category. The inline finding by Ritter et al. (2020) is that the originality component did not differ significantly during the creativity training process. Originality is distinct and uncommon, involves taking intellectual risks to generate unusual problem-solving ideas, and always involves rational thinking (Gomez, 2007). Although in this study the achievement of originality as a component of creativity is still in the low category, it is necessary to train. Shimonaka and Nakazato (2007) found that creativity develops with individual maturity, and several influential factors, such as personality, openness to experience, and problem-solving ability, have significant correlations with creativity.

FAC was evaluated through student activities that created mind maps on stoichiometry, which involved procedural knowledge. Ableitinger and Dorner (2023) stated that students' success in mastering procedural knowledge depends on their conceptual knowledge, as there is a two-way interaction between the two. It means that students can solve stoichiometry calculations in chemical reactions as procedural knowledge by applying the conceptual knowledge they have understood. When students performed stoichiometric calculations, it involved their cognitive skills. Wang and Chiew (2010) investigated students' cognitive structures that used retrieval memory to link alternative procedures to the solution goal when solving a calculation. This underlies the application of the knowledge network constructed in the cognitive structure to determine the initial procedure for solving stoichiometric calculations. In addition, integrating digital literacy is needed to strengthen students' knowledge. Their internet skills affected academic achievement (Pagani et al., 2016). The usage of technology in chemistry learning can reveal the macro-micro-symbolic representation, thereby increasing procedural knowledge (Hagos & Andargie, 2023). Students were required to demonstrate their knowledge of digital literacy by creating a creative mind map. Mind maps can promote students' creativity by offering a hierarchical structure supported by open-access information in the digital era (Siwczuk, 2005). The main difference between mind maps and concept maps is that mind maps do not adhere to a strict hierarchical structure. Mind maps also help students understand stoichiometry in detail through individual experience. The achievement of FAC components is presented in Table 3.

Table 3. Mean Score of FAC in Each Component

Component	M	SD	Students (%)		
			High	Moderate	Low
Fluency	89.3	31.2	0.0	89.3	10.7
Originality	0.0	0.0	0.0	0.0	0.0
Elaboration	0.0	0.0	0.0	0.0	0.0
Resistance to Premature Closure	7.5	1.9	3.6	91.6	5.4
Abstractness of Titles	55.4	50.2	0.0	55.4	44.5

Students' fluency and the abstractness of their titles were higher than in premature closure. However, Students' creativity in originality and elaboration was not available. Originality delineates the novelty of the product, which is rarely present in students' mind maps, because they tend to map concepts according to the hierarchy when discussing materials with lecturers in class. Students focused on the lecturers' material, which limited their ability to be original and creative when constructing mind maps. The inline finding by Anderson and Graham (2021) was that carrying out the originality task takes more time because it involves a higher level of creative illustration, and this was supported by students' self-confidence, metacognition, and cognition. Maria et al. (2022) concluded that originality is the novelty of a product so that it can be distinguished from other existing products. It can be improved by analyzing gaps in existing products and communicating the novelty of ideas to colleagues or lecturers to get feedback.

Originality is a central component of creativity, which can be pursued through divergent thinking skills that generate many ideas without being limited by anything and through the implementation of the SCAMPER Technique (Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, and reverse) (Acar et al., 2017). A substitute replaces elements of a process or product. It was initially done individually, but it can be changed to group work because it allows for interactive discussion and unlimited exploration of knowledge. Combine is the merging of two or more mind map products into one innovative product. Adapt is refining the idea of a mind map, which initially contained brief concepts, including symbolic aspects, and can also be integrated with microscopic and macroscopic aspects. Modify is changing the appearance of the mind map product to make it more attractive by using an image. Put to Another Use is the usefulness of the mind map, which is expanded not only to make it easy to memorize the stoichiometry formula but also to provide its application for solving everyday problems. Eliminating is removing unnecessary elements when constructing a mind map, such as referring to just one book. The reverse is returning the process to producing new ideas, which initially involve concepts but can also be integrated with procedural knowledge (e.g., stoichiometry in chemical equations).

In this research, the FAC creativity product (mind map) lacked an elaboration component, which involves a deep understanding of concepts and requires students' reasoning skills to link them in the mind map. Students only showed mathematical formulas and short definitions as symbolic representations. Shively (2011) revealed that the elaboration component delineates the depth of creative ideas, and its application in the field of science is as visualization. In chemistry learning, visualization in the form of macroscopic (contextual phenomena) and microscopic (chemical particles) can be integrated into a mind map. Wijayati et al. (2019) concluded that elaboration increased through project assignments completed within a specific period of time. The main finding of this research was that creativity elaboration during making cannot be trained by simply constructing a single mind map; it requires more practice time. Green et al. (2024) concluded that creativity involves cognitive abilities for exploring, evaluating, and creating new ideas, which are improved through experience/practice. Lecturers assisted students in exploring chemical representations (macro, micro, and symbolic) through digital literacy and in expressing their knowledge through mind maps. It was an innovation in the use of technology in chemistry learning, especially for those rich in procedural knowledge, such as stoichiometry. Abbas et al. (2019) found that digital literacy is correlated with communication skills and students' self-confidence. This research also found that digital access made it easier for students to think critically, sort information, and convey it in written communication as a mind map, thereby generating confidence that they had succeeded in creating one. The following is a sampling of mind map products by student-3 as displayed in Figure 4.

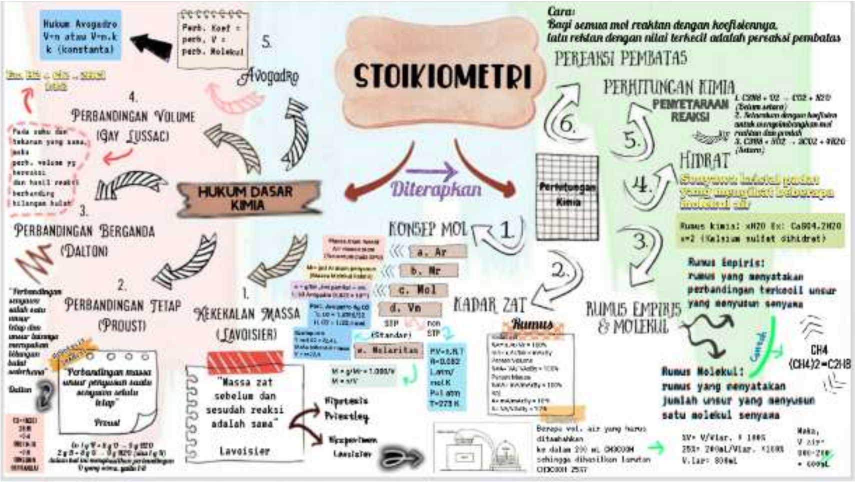

Figure 4. Sampling of Students' FAC Creativity

Based on Figure 4. The mind map by student-3 has categories fluency (moderate), abstractness (moderate), and resistance (moderate). Student-3 succeeded in mapping to the last descendant hierarchy, namely the example, so that the components of fluency, abstractness of titles, and resistance to premature closure had moderate categories. In that mind map, there are mathematical equations/definitions (symbolic aspects) and experimental images (macroscopic aspects), but student-3 could not integrate knowledge of limiting reactants to evaluate the validity of Lavoisier's law in a chemical equation. Students tended to focus on adding up the mass before the chemical reaction as the mass of the reactant and the mass after the chemical reaction as the mass of the product, without considering the mass of the excess reactant. This finding indicated that students had not been able to integrate knowledge of limiting reagents into stoichiometric equations for evaluating the validity of Lavoisier's law. When students process knowledge, they refer to the cognitive load theory, which holds that working memory has limitations and requires encoding before knowledge is transferred to long-term memory (Brame, 2017), which can be achieved by constructing a mind map and presenting contextual phenomena. When students integrate knowledge (some concepts in a mind map) to solve problems that directly involve critical thinking skills. Mind maps significantly improved critical thinking skills by actively engaging students in connecting concepts (Jesus, 2024). Based on Figure 3, the mind map does not explicitly link concepts, which is why Students-3 are unable to integrate knowledge of limiting reagents to evaluate the validity of Lavoisier's law in stoichiometric chemical reactions. Presenting the phenomenon of "The Martian Movie" should also help students understand that the formation of water requires stoichiometric calculations to prevent an explosion from excess reactant (hydrogen gas). The students just proved the stoichiometric calculation of moles (initial, reaction, leftover) without converting moles to mass of the excess reactant (hydrogen gas) and product (water vapor) as the mass after the reaction which would be compared with the mass before the reaction of the reactants (hydrogen gas and oxygen gas) to emphasize the validity of the law of conservation of mass.

The knowledge is documented in the mind map, which helps students act as independent learners. They actively engaged in mapping the details of the concept. Students' creativity in creating mind maps is evident in the attractive designs and the diverse mapping results. Utilizing knowledge in the mind map requires students' ability to decide which concepts to use when solving problems. It involves students' mental processes of identifying the main problem and analyzing relevant knowledge to solve the problem, as a form of critical thinking skill (Papathanasiou et al., 2014). The findings of this research were that students with detailed knowledge of mind maps did not necessarily find it easier for them to decide which concepts to use to solve the problem. The decisions were of high quality, using "decision trees" to solve problems in small steps for deeper analysis (Turan et al., 2019). Future recommendations to be able to train critical thinking skills as a follow-up to the use of mind maps that have been prepared by involving student creativity.

The majority of first-year students' mind maps reflect the components of FAC—fluency, abstractness of titles, and resistance to premature closure—in the high-moderate category, while they do not reflect the components of originality and elaboration. Students cannot create relationships or crosslinks in a mind map. Mind maps may be used as a tool for detecting how students construct knowledge (Zvauya et al., 2017), so that, in future research, lecturers need to guide students in interpreting relationships between concepts through the presence of relationships and crosslinks. Wang et al. (2010) concluded that mind maps significantly improved analytical, reasoning, and creativity skills because of their structured format, which enables students to manage diverse information and encourages the emergence of new ideas. So that learning involves students' participation in making mind maps individually, which can be helpful in coaching in creative thinking and for making stoichiometric material easier to understand.

Scholastic ability in chemistry assessed students' reasoning in the field, which is thought to be a predictor of success in delivering lectures in higher education. Schult et al. (2016) stated that first-year students naturally have reasoning, numeric, and verbal abilities, as measured by scholastic tests, and Fasko (2006) stated that creative ideas are generated from the reasoning process. So the students' scholastic abilities in chemistry may have contributed to the creation of creative products. Scholastic ability involved students' ability to solve problems in the N (numeric), VR (verbal and reasoning), or NVR (numeric, verbal, and reasoning) domains. When students can solve problems in VR and NVR, they are thought to have high reasoning ability, which influences high creativity (VAC/molecular model and FAC/mind map) in stoichiometry learning. The role of reasoning that exists in students is: (i) how to use technology and evaluate information digitally to determine daily life materials that can be used for molecular modeling, and (ii) analyze the results of knowledge exploration through the internet used to make a mind map (Ilomäki et al., 2011; Bouhnik & Giat, 2009). The correlation between scholastic ability in chemistry and creativity is presented in Tables 4 and 5.

Table 4. The correlation of chemistry scholastic ability and VAC

Variable	N	Sig. (2-tailed)	r
Chemistry scholastic ability and VAC	56	0.001	0.417

Table 5. The correlation of Chemistry scholastic ability and FAC

Variable	N	Sig. (2-tailed)	r
Chemistry scholastic ability and FAC	56	0.731	-0.047

The significance value is less than 0.05, indicating a correlation between the two variables (Cresswell, 2012). Based on Table 4, there was a significant correlation between chemistry scholastic ability and VAC (r = 0.417), indicating a strong relationship but not a significant factor (Cresswell, 2012). While in Table 5, there is no significant correlation between chemistry scholastic ability and FAC. Chemistry scholastic ability significantly affects VAC creativity but does not affect FAC creativity. This shows that scholastic ability in chemistry is not a predictor of student success in stoichiometry, which involves activities such as making molecular models and mind maps as products of creativity.

Chemistry scholastic ability had a significant correlation with VAC. This means that scholastic ability in chemistry affected students' VAC. The majority of students had N-type and VR-type scholastic abilities in chemistry, one of which involves reasoning, so they had creative ideas for making molecular models (molymood) from plasticine, toothpicks, wood, ice cream sticks, flour dough, and food coloring. The research found that all components of VAC (flexibility, fluency, originality) are achieved by students, even though the originality component had a low mean score. They made a molecular model that represents a single bond between atoms and rarely uses double/triple bonds. They focused on the virtual molecular orbitals of CH_4, which have a single bond, as shown by the lecturer. The originality of VAC requires a high level of reasoning, which can be achieved if students have scholastic ability up to NV level. Amir and Mohamed (2022) found that students' reasoning ability in the fourth semester was higher than in the first semester, because, along with increasing experience in modern teaching, this can stimulate students' thinking skills. Modern teaching places students at the center of learning.

Chemistry scholastic ability did not correlate significantly with FAC creativity. This was supported by a few students with chemistry scholastic ability, of the NVR type, with a low average. Wang et al. (2021) concluded that students' reasoning ability was positively affected by their mindset. Limeri et al. (2020) found that students with a fixed mindset tend to underdevelop intelligence/ability, avoid challenges, and give up easily. Nevertheless, this research found that students successfully overcame the challenge of creating a mind map of stoichiometry for the first time. They engaged in a learning process that combined discussion with the lecturer and digital literacy, resulting in knowledge acquisition. They actively organized and visualized it as FAC creativity in the form of a mind map, even though only a few components were achieved (fluency, resistance to premature closure, and abstractness of title). All of the students' mind map did not reflect the originality and elaboration components of FAC creativity. There was no originality in the mind map because students relied too much on the material limits described by the lecturer as a basis for their exploration of knowledge in digital literacy. There was no elaboration of the mind map because students had not been able to make a concept link—a mental process that explains the interrelationship between concepts. They identified that they find it difficult to integrate more than one concept to solve a problem.

The scholastic chemistry ability of first-year students showed moderate-level reasoning in stoichiometry. Few students had solved the NVR type problem; they experienced difficulty transforming the microscopic representation (particle images at the beginning and end of the reaction) into the symbolic representation (stoichiometry calculation in a balanced chemical equation). Students could not yet think abstractly, even though, according to Piaget's theory, they had entered the formal operational stage of cognitive development. This proves that first-year students did not yet have a deep understanding of the chemistry subject through the triple representations (macroscopic, microscopic, and symbolic). Anggraeni et al. (2022) found that validating students' conceptual knowledge of the truth of concepts at three levels of chemical representation is needed before applying algorithmic knowledge, so that students have a deep understanding that can solve stoichiometry problems in varied circumstances. Stoichiometry learning at the secondary school was carried out by presenting stoichiometry calculation procedures as a symbolic aspect, followed by individual exercises. This affected first-year students' ability to solve stoichiometry problems at the particulate level without knowing the numeric data. McNemar (1955) stated that learning experience and environmental factors can limit students' reasoning. The selected prospective students did not yet have high-level reasoning in the chemistry subject; thus, it is generally believed that chemistry is learned by memorization rather than through a deep understanding of the triple representations. This supports decision of the Minister of Education, Culture, Research and Technology of the Republic of Indonesia No. 48 of 2022 that eliminate the academic competency test (the fields of mathematics, chemistry, physics, biology) and focus on scholastic test and literacy test which prioritizes reasoning ability as a guidelines for the admissions process for new students at state universities in Indonesia since 2023.

Creativity, as one of the 21st-century skills, requires students' reasoning ability, which can be developed through stoichiometry learning using activity-making molecular model (VAC) and mind map (FAC) activities. The originality component of creativity appeared in VAC but did not appear in FAC. Originality, as the main component, expresses ideas that differ from previous ones, encouraging innovation and inspiring others (Runco & Charles, 1993). The originality of VAC creativity was shown by several students, who used colored flour dough for atomic modeling or toothpicks for atomic bonding. Students' creative ideas in choosing easily degradable materials could train them to become critical thinkers who promote awareness and prevent environmental pollution. In addition, they used plastic straws for bond modeling between atoms to minimize waste generation by reusing/recycling. Corazza (2016) concluded that originality was a significant component of creativity, dynamic, and useful for students' decision-making in the face of technological dominance.

The rapid digitalization requires students' ability to select scientifically correct information (conceptual/procedural knowledge). Ableitinger and Dorner (2023) found that first-year students tend to rely on the internet to solve algorithmic calculations, which affects procedural knowledge. This shows that procedural knowledge is generally acquired through teacher-centered instruction, which has not significantly affected mastery of knowledge. Therefore, this research combines teacher-centered learning with mind mapping in stoichiometry learning. Direct experience of students in processing information and expressing thoughts in mind maps, which activate students' cognitive structures. When students process knowledge, it involves elements of perception, memory, thinking, and language, thereby raising awareness of how they learn (Zhao, 2022) and motivating them to learn, which in turn increases procedural knowledge (Saks et al., 2021). Students' direct experience in articulating conceptual knowledge through a mind map makes it easier to apply procedural knowledge across various contexts. This supports the research findings that the majority of first-year students were able to solve problems of N and VR types, although only a few were able to solve problems of the NVR type. First-year students succeeded in formulating stoichiometric calculation patterns using metric units (mass, mol, etc.), but they struggled to transform particulate representations into stoichiometric calculations for chemical reactions. According to Basir and Waluya (2022), they can be classified as having a symbolic representation cognitive structure, involving a moderate level of algebraic reasoning.

Another finding of this research was that none of the students' mind maps reflected the originality component of FAC creativity. Students' mind maps show material limitations similar to those discussed with the lecturer in class. Originality in the mind map is predicted to appear if it contains knowledge outside the limitations of the lecturer's material and relevant images related to the application of stoichiometry in everyday life (the importance of stoichiometry calculations in the ammonia/plant fertilizer industry do not produce excess hydrogen gas explosive) along with microscopic image shows the state of particles during chemical reaction (beginning, reaction process, end/final). In line with Dong et al. (2021), originality would appear in the mind map by adding short narrative text and images, thereby distinguishing it from the mind map in general, which involves mapping activities and crosslinking concepts.

Chemistry scholastic ability significantly affects VAC creativity but does not significantly affect FAC creativity. The other factors are thought to affect FAC creativity in this research, supporting Jenkins's (1992) statement that the impact of scholastic ability on educational implementation is still a matter of debate. Slack (1980) concluded that scholastic ability slightly predicted academic performance in higher education, while Eze et al. (2015) stated that scholastic ability does not significantly affect student performance. Bahník and Vranka (2017) stated that scholastic ability is negatively correlated with growth in student mindset. Although scholastic ability in this study did not consistently affect both types of creativity (VAC & FAC), it still needed to be trained in the first year in solving stoichiometric problems with microscopic representations that require reasoning, verbal, and numerical abilities.

CONCLUSION

The scholastic ability of first-year students in stoichiometry learning significantly affected verbal assessment of creativity (VAC), but it did not significantly affect figural assessment of creativity (FAC). Students had moderate reasoning ability because they had not successfully transformed their understanding to a microscopic or symbolic level. Reasoning ability refers to how students use knowledge to make decisions or solve problems. It was found in the form of choosing environmentally friendly materials for molecular modeling (VAC), which indicated the originality of the creative idea. In comparison, originality was not apparent in the mind map product (FAC), which just contained knowledge mapping without additional images of stoichiometry, real-world applications, or particulate images of chemical reactions (initial substances, reaction process/atoms rearranging & bond forming, and final substances). The first-year students of chemistry department were found that they had not high enough reasoning in chemistry field as a basis for strengthening the policy of the Ministry of Education and Science and Technology has eliminated subject-specific science and technology tests (including chemistry) in the National Selection Based on Test (SNBT) for new student admissions academic science and technology tests (including chemistry) in the higher education. Suggestions for further research include university-level chemistry instruction that integrates three representations (macroscopic, microscopic, and symbolic) to develop reasoning skills in the field of chemistry, thereby enhancing creativity as one of the essential 21st-century skills.

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