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Profile of Concept Understanding and Scientific Argumentation Skills on Genetic Material of Grade XII MIPA Students of SMA Laboratorium UM

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ABSTRACT

Scientific argumentation skills as an intellectual practice can involve students in constructing and criticizing scientific ideas related to science literacy. The purpose of this study is to find out the scientific argumentation ability of high school students with different conceptual understandings. This study was designed as a survey involving students in grade XII of MIPA SMA Laboratorium UM. The results show that the highest average value of understanding the concept of genetic material was 87,22 and the lowest average value was 69,00. Indicator of scientific argumentation "claims and warrants" have an average value of 67.33; the "counterargument" indicator is 84.89; the "supportive arguments" indicator is 63.75; the "evidence" indicator is 83.19. The most appropriate solution to improve students' scientific argumentation skills is to apply an innovative learning model that involves argumentative dialogue in the classroom. Argumentation Driven Inquiry (ADI) is an argumentation and inquiry-based learning model that can be used as an alternative to empower students' scientific argumentation skills. On the other hand, students with low conceptual understanding scores managed to achieve the category of excellent scientific argumentation: good, enough, less, very little. This condition shows the importance of implementing innovative and argument-inquiry-based learning.

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1. INTRODUCTION

Science educators, scientists, and policymakers agree that the development of students' science literacy is an essential goal of science education itself (Gormally, Brickman, & Lutz, 2012). Evidence that science literacy is critical to learning is reflected in science education in primary schools, which allows children to learn scientific content knowledge as well as scientific reasoning and scientific argumentation skills from an early age (Schlatter, Molenaar, & Lazonder, 2020). Today, scientific argumentation and reasoning are pedagogical practices and core competencies in science learning in many countries (Giri & Paily, 2020). Students' participation in scientific argumentation can enhance their conceptual, epistemological, and methodological understanding of science (Sampson & Blanchard, 2012). Engaging in science as argumentative and reasoning practices can encourage students' critical thinking, reflection, and evidence evaluation (Bathgate, Crowell, Schunn, Cannady, & Dorph, 2015);(Erduran & Jiménez-Aleixandre, 2007). Thus, the pedagogy of scientific argumentation can be utilized in the science learning ecosystem to utilize higher-level thinking skills and other 4C (*Critical, Creative, Collaborative, and Communication*) skills. According to Simon (Simon, Erduran, & Osborne, 2006) science teachers still consider scientific argumentation and reasoning to be challenging and complex to teach. Teachers expressed anxiety about presenting alternative theories to students (i.e., competing explanations for how we see objects) as they thought these might cause confusion for students and strengthen their beliefs in scientifically incorrect ideas; but, by the end of the year, these fears had diminished.

Students, as part of society, really need science and technology as the basis of their thinking; with science and technology as the basis of their thinking, it is essential to cultivate wise and rational thinking (Evagorou & Osborne, 2013);(Dana L. Zeidler., 2009). Therefore, improving scientific argumentation skills in schools will be essential to encourage the advancement of science, technology, and society. In science classrooms, educators want to cultivate students who have science knowledge and who can collaborate effectively. In science classrooms, educators want to cultivate students who have science knowledge and who can collaborate effectively. Science learning requires classrooms that provide opportunities for students to work together in a variety of ways to create new perspectives (Songsil, Pongsophon, Boonsoong, & Clarke, 2019). Students should be able to identify sources for their research and reasoning in a rational and evidence-based manner that increases the problem-solving potential for social problems (Lazarou, Sutherland, & Erduran, 2016).

In Indonesia, scientific arguments are closely related to important issues in the future, especially 21st-century skills. Scientific argumentation fortifies the claim method by emphasizing the ability to be precise in ideas and concepts around scientific phenomena in life based on evidence and its relevance to existing hypotheses. 21st-century skills also include argumentation skills. Argumentation as an intellectual practice can involve students in constructing and criticizing scientific ideas (Lazarou et al., 2016). Argumentation allows students to engage in a variety of scientific practices of society and culture through exploratory activities during learning and deepen their understanding of the meaning of science (Tsai, Lin, Shih, & Wu, 2015). Students will gain experience from scientific practice, and that experience can be used to justify and support their arguments (Chowning, Griswold, Kovarik, & Collins, 2012). Scientific argumentation is usually associated with understanding and knowledge of scientific concepts and practices (Myers, 2015);(Yi, Çetin, & Do, 2014). Students need to do a series of activities to build the correct argument. The process begins with the collection of claims and data (ground) and continues with the provision of reasons (warrants), backing (backing), qualifiers, and rebuttals (Mei-Chun Lai, 2012). Strong argumentative reasoning will have a positive impact on improving students' scientific communication and writing skills (Kong, Y. T., 2016).

Knowledge of the content is essential because understanding the topic and the basic concepts associated with the topic allows individuals to provide more reasons to support a claim or show examples, where there is a connection made between the claim and the evidence used to support it, is inappropriate or irrelevant (Sadler, 2004). An adequate understanding of the basic concepts related to a particular topic, however, may not be helpful if the student does not know how to construct an argument using this knowledge. Therefore, in the research literature, there is still much debate about what needs to be known or at least familiar for students to participate in the process of scientific argumentation in a productive way (Sadler & Donnelly, 2006). A literature review shows that content knowledge and understanding of the norms of scientific argumentation can influence how students participate in scientific argumentation. Some researchers, including McNeill & Krajcik (McNeill & Krajcik, 2007) and Osborne (Osborne, Erduran, & Simon, 2004) have reported that students struggle when trying to participate in scientific arguments in school because they lack an understanding of how the nature of scientific arguments differs from arguments that occur in other contexts (e.g., home, school, peer groups, non-scientific disciplines). Other researchers also argue that people need adequate content knowledge to participate in arguments of a scientific nature (Sadler & Fowler, 2006);(Sandoval & Millwood, 2005). The researcher claims that individuals need to have an adequate understanding of the concepts and theories related to the topic because the analysis and interpretation of data in science are loaded with theory.

2. RESEARCH METHOD

This study uses a survey method with a quantitative descriptive approach to investigate the understanding of concepts and scientific argumentation skills. This descriptive research aims to measure a particular social phenomenon. The research participants consisted of 177 students in class XII MIPA SMA LAB UM (XII MIPA 1-5). Researchers are interested in using this sample because UM Lab High School students come from various regions with heterogeneous backgrounds and are not affected by the student zoning system as in public schools. Scientific arguments were tested with questionnaires using the *Argumentation Skills Questionnaire* (ASQ) rubric from Lin & Mintzes (Lin & Mintzes, 2010), which was compiled related to the topic "Genetic Material." At the same time, the understanding of the concepts tested was also related to the concepts in the chapter on genetic material. According to Lin & Mintzes, the indicators of scientific arguments include four indicators: 1*) Claims warrants, 2) Counterarguments, 3) Supportive arguments, 4) Evidence* with scores varying from zero if not answered/wrong answers and will increase by one depending on the number of claims/guarantees/comparative arguments/supporting arguments and evidence provided by students. Data collection was carried out after all sample classes had been given the chapter "genetic material" and at the last meeting was taught explicitly with the "*case methods" learning model* on the sub-topic "protein synthesis and CRISPR technology" to introduce students to scientific argumentation skills. The following is the rubric of the assessment of scientific argumentation questionnaires related to the topic of "genetic material," which can be seen in Table 1.

Table 1. Scientific Argumentation Assessment Rubric

Question	Categories	Answer	Assessment and explanation
Q1—Claims and warrants	No answers or guarantees	No answer/I don't know	0
	Only claims are acceptable and there are no guarantees	I disagree	1 (one point for each claim)
	Claims accepted and guarantees are valid	I disagree. Because it violates the code of ethics	1+1 (one point for claims plus one point per guarantee)
	Acceptable claims and more than one valid guarantee	I disagree. Genetic engineering itself is experimental and is still related to missed mutations, which can cause genetic problems from early to later in life, including the growth of cancer cells.	2+1 (one point for each additional guarantee)
Q2—Counterarguments (compare Q1)	No answers or guarantees	No answer or I think it's true.	0
	One or more valid warranties	The results of CRISPR ensure that problematic genes can be removed so that humans can avoid genetic diseases	1+ (one point for each guarantee)
Q3— Supportive arguments	No answers or guarantees	No answers or still need strong support	0
	Guaranteed spelled out and valid	The experiment puts normal, healthy children at risk of gene editing, with no significant benefit.	1+ (one point for each warranty outlined)
	Additional and valid guarantees	This technology is very ethically problematic, because changes in the embryo will be passed on to the next generation and will likely have an effect on the entire gene pool (or gene pool)	1+ (one point for each added guarantee)
	Objection to counterargument (compare Q2)	Scientists are allowed to conduct genetically engineered research on embryos produced by unused IVF, as long as the embryos from the experiment are immediately destroyed, and not used to develop into babies.	2+ (two points for each rebuttal
Q4—Evidance	No additional evidence or explanation	Emptying or not allowing the CRISPR practice that He Jiankui did is correct.	0
	Valid evidence	A new study states that edits in DNA like those experienced by Lulu and Nana have been done in mice. As a result, the mice became smarter. MIT Technology Review reports that this unexpected result is caused by the deletion or mutation of a gene called CCR5, which researchers believe can affect memory and the brain's ability to form new connections. HIV requires the CCR5 gene to enter human blood cells.	1+ (one point for each dedication)

3. RESULT AND DISCUSSION

Figure 1 shows the profile of understanding the concept of genetic material tested in five classes of MIPA at the SMA Laboratorium UM.

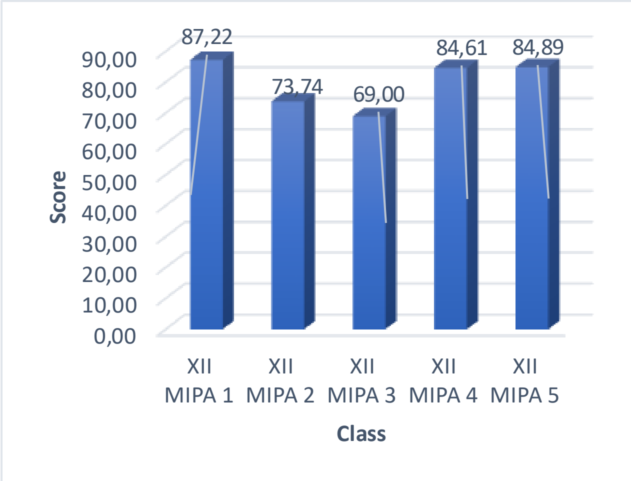

Figure 1. Average score of understanding the concept of genetic material

The highest average score of understanding the concept of genetic material in class XII MIPA 1 was 87.22, while the lowest average in class XII MIPA 3 was 69.00. Concept comprehension scores consecutively for XII MIPA 2; XII MIPA 4:XII MIPA 5 is 73.74; 84,61; 84,89.

Based on the score obtained from the scientific argumentation test, the average score for each indicator of students' scientific argumentation was obtained as follows in table 2.

Table 2. Average Score of Each Scientific Argumentation Indicator

Indicators of Scientific Argument	Average
Claims and warrants	67,33
Counterarguments	84,89
Supportive arguments	63,75
Evidance	83,19

Scientific arguments in the "claims and warrants" indicator have an average value of 67.33; the "counterargument" indicator is 84.89; the "supportive arguments" indicator is 63.75; The "evidence" indicator is 83.19. Based on the student's answers, many students quickly say they agree or disagree but find it challenging to compose arguments or counterarguments. They are too complex to provide scientific and systematic explanations. This is in line with Golanics and Nussbaum (Golanics & Nussbaum, 2007), who state that students are challenged to formulate arguments or counterarguments due to low knowledge and social issues. Many students also avoid disputes and explore counterarguments. These findings suggest that teachers need to use a variety of learning models, such as socio-science approaches. The socio-scientific approach can be in the form of thinking that contains situations and social conversations that arise along with the progress of science and innovation and convey moral and ethical implications. Socio-scientific issues also have a scientific basis; describing controversial issues and containing political and social measurements are considered to be some of the characteristics of good socio-scientific issues (Sadler & Donnelly, 2006).

Students' Scientific Argumentation Skills Based on Differences in Concept Understanding Score

The difference in students' argumentation skills with high and low concept comprehension scores is closely related to their thinking ability. Students who have a high understanding of concepts are learners who learn quickly. They have good long-term memory and have an impact on their academic achievement (Mahanal, 2019) and higher-order thinking skills. Research has shown that a student's academic ability can affect the way students present their arguments. Students with high academic ability have better argumentation skills than students with low academic ability (Nurramadhani, Annisa., 2017) because students with high ability are more skilled in collecting data and evidence. They are also able to communicate the results (Osborne et al., 2004);(Kollar et al., 2014). Poor student argumentation skills can also be caused by the unavailability of learning materials that can improve students' thinking skills. In fact, learning is dominated by activities that do not accommodate students' higher-order thinking and argumentative skills. Argumentative dialogue has become a habit that can improve students' argumentation skills (Crowell & Kuhn, 2014). Therefore, suitable learning materials accompanied by innovative learning models can ultimately empower students' argumentation skills.

Student's Scientific Argumentation Based on the Argumentation Skills Questionnaire (ASQ) from Lin & Mintzes

Scientific argument means that a person tries to create, support, oppose, or improve scientific claims in order to produce credible validation and conclusions. The conclusion must be based on data and empirical evidence (Evagorou & Osborne, 2013);(Lin & Mintzes, 2010). The main common element is claims made and supported by guarantees (reasoning), which in turn are based on evidence (data). Lin & Mintzes and Toulmin have an additional element in it: support to support the claim (supporting argument) (Lin & Mintzes, 2010);(Toulmin, 2003). Furthermore, Lin and Mintzes added counter-arguments to encourage students to recognize and discuss views that differ from their original perspectives and to be open to the opinions of others. Lin and Mintzes' framework encourages students to consider and refute counter-arguments. This rebuttal process does not exist in any other framework. This will help teachers understand why some students develop stronger arguments than others to design more effective argument-based inquiry teaching models in science classrooms. The following are examples of test questions and students' answers to scientific argument questions based on indicators developed by Lin and Mintzes.

"Presented a social-scientific issue in the form of an article related to the CRISPR phenomenon about CCR5 gene editing to prevent babies from contracting HIV from parents with HIV and the gene edited babies accidentally become intelligent due to the impact of CCR5 gene editing improving cognition and memory ability". Then, students are given four questions as follows:

Q1: Do you agree with the actions taken by He Jiankui (a Chinese researcher) who has edited the baby's DNA using CRISPR technology? Write down your ideas/reasons for your opinions! (Assesses students' ability to make claims and warrants).

A1: "I disagree, because I think that editing human DNA is a violation of the code of ethics even if it has good intentions such as improving cognition and HIV resistance. DNA editing must be approved by the person concerned, while the baby has not been able to decide what action he will take so that he cannot consider the impact that will be obtained by him" (Claim accepted and guarantee valid)

Q2: If someone disagrees with the opinion you outlined in the first question and he or she has specific reasons for disagreeing with your opinion. What is the reason that the person has? (Assesses students' ability to construct counter-arguments)

A2: "If after DNA editing with CRISPR does provide great benefits (improved cognition, HIV resistance) and does not pose any health risks then it will be very beneficial for the baby as a result of the DNA editing, here the parents as the responsible holder and the doctor/everyone involved must also be responsible for the health risks of the baby" (Counter argument and guarantee)

Q3: How do you convince someone who disagrees with you if they give a reason like the one in the second question (Q2)? (Assesses students' ability to generate supportive arguments, including rebuttals)

A3: "Even if the baby experiences cognitive improvement so that he will become an intelligent individual and also immune to HIV, this will have an impact on his social life, especially when in public schools or there is a community stigma related to HIV-resistant individuals as if they will be able to act freely without worrying about contracting/transmitting HIV so that there is a social gap or in other words no one can guarantee and be responsible for the risk in the future. (Objection to counter-argument)

Q4: If you were asked to provide evidence to support your opinion, in question 1 or 3, what kind of evidence would you present? (Assesses students' ability to generate evidence)

A4: Scientists have only proven cognitive improvement in mouse organisms. Other risks if CCR5 gene editing is applied to humans have not been scientifically reported. The structure and physiology of animal and human cells are also different in complexity (Valid evidence).

Improving Scientific Argumentation Skills through the Learning Model

A learning model is needed that can help students identify, apply, and analyze scientific concepts and be able to communicate them in the form of written and oral arguments based on scientific reasoning that has been carried out during learning. The ADI *(Argumentation Driven Inquiry)* model is a model that gives students the opportunity to build their explanations and share their ideas while socializing in small groups or during class discussions. This creates a classroom atmosphere that provides a cultural process for the teaching of science (Sampson & Blanchard, 2012). According to Demircioglu, ADI is also considered a practical model because it gives students the ability to share and evaluate their products with each other, improve communication and writing skills, understand the construction of scientific knowledge, and have the opportunity to experience things firsthand (Demircioglu & Ucar, 2015). The syntax of the ADI model is quite varied because there are several modifications/developments from experts, so it often has the name rADI (revised-ADI) or mADI (modified-ADI). The rADI model developed by Songsil et al (Songsil et al., 2019) has 9 stages, which includes: (1) determining students' prior knowledge;(2) data and research activities in group;(3) free exchange of scientific explanation;(4) presenting socio-scientific issues;(5) Data/Research activities in groups 2;(6) Make tentative claims about SSI as a group;(7) Engaging in argumentation as a class;(8) The creation of a written investigation report by groups of students; (9) Engaging in peer review and revising group reports. This learning model can be implemented in a structured manner and also deliberately builds a classroom atmosphere that can help students understand the explanation of scientific explanations, how to give opinions with scientific evidence and understand the facts of scientific knowledge (Victor, Jonathan, & Joi, 2010).

4. CONCLUSION

The results of this study show that the majority of students in grade XII MIPA SMA Laboratorium UM have good argumentation skills but still have difficulties in presenting arguments and providing valid evidence for their arguments. In other words, argumentation skills still need to be improved. Indicator of scientific argumentation "claims and warrants" have an average value of 67.33; the "counterargument" indicator is 84.89; the "supportive arguments" indicator is 63.75; The "evidence" indicator is 83.19. It was also reported that there was a difference between students' scientific argumentation skills and high and low conceptual understanding. The highest average value of understanding the concept of genetic material in class XII MIPA 1 was 87.22 and the lowest average value in class XII MIPA 3 was 69.00. The most appropriate solution to improve students' scientific argumentation skills is to apply an innovative learning model that involves argumentative dialogue in the classroom. *Argumentation Driven Inquiry* (ADI) is an argumentation and inquiry-based learning model that can be used as an alternative to empower students' scientific argumentation skills.

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