Students' Argumentation Skills: Does It Need Strengthening?

Viyanti[1,2], Cari[3], Widha Sunarno[3], Zuhdan Kun Prasetyo[4]
[1]*Program Studi Doktor Pendidikan IPA, Universitas Sebelas Maret, Surakarta, Indonesia*
[2]*Program Studi Pendidikan Fisika, Universitas Lampung, , Bandar Lampung, Lampung, Indonesia*
[3]*Program Studi Pendidikan IPA, Universitas Sebelas Maret, Surakarta, Indonesia*
[4]*Program Studi Pendidikan IPA, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia*

Keywords: Physics Learning, Archimedes Principle, Assessment Argumentation, Production Argumentation, Understanding Concept

Abstract: Physics learning is directed at ways of thinking and submitting scientific statements. Students' understanding of how to think and propose scientific statements change better as argumentation skills are strengthened. The purpose of this study was to analyse the construction of the decomposition of quality argumentation production in strengthening argumentation skills using the argued skills assessment instrument. The method used in this research is descriptive survey method. The subjects of this study were high school students in Bandar Lampung City Region, amounting to 50 class XI students and had obtained Archimedes principle material. Data was collected using reasoned multiple choice tests and interviews. The specific role of the argumentation skill assessment instrument in this study shows that: the structure or complexity of the argument strengthened 51.7%; fill in the argument 27.3% and the nature of the statement of reason 24.0%. The results of this study allow researchers to develop learning strategies to strengthen argumentation skills and improve learning environment technology to promote and support more productive arguments in the classroom.

1 INTRODUCTION

One of the objectives of learning science is to generate new knowledge about natural phenomena. NRC (2012) science education standards need to incorporate practices, concepts and arguments. Physics is one of the subjects in the science cluster; therefore physics is expected to provide direct experience to students. One study of physics that provides direct experience to students is the material of Archimedes' principles. But in fact, teachers have difficulty to provide direct experience in learning. This is consistent with the results of the study which are: 1) (Knight, Wise and Southard, 2013) teachers are doubts to get out of conventional learning as a result (1) teachers lose class control, (2) if the discussion activity takes a lot of time, and

An attitude of scepticism: whether students are able to learn on their own. The limitations of teachers providing direct experience to students (learning outcomes as in Figures 1a, 1b, and 1c) are allegedly caused by: (1) the lack of mastery of information on how Archimedes principle material can be visualized and (2) learning leads to memorization resulting in a lack of mastery of students' concepts.

Students' abilities presented in Figures 1a, 1b, and 1c are built from cognitive abilities and discourse of transfer of knowledge from teacher to student. This results are a lack of: (1) the ability to visualize statements, (2) students' awareness of the theory being studied; (3) knowledge compiles statements related to the theory being studied; (4) learning variation (only transmission of knowledge and opinion); (5) explain the reason for the statement; (6) involves initial knowledge in preparing statements; (7) conceptual understanding; (8) time to produce statements; and (9) reasoning with logical confirmation. This data is in line with research (Driver, Newton and Osborne, 2000) that students are not ready to analyse knowledge to build statements. This illustrates that the existence of learning complexity that needs to be evaluated in order to help students contribute to mastering the concept with the processes suggested in learning.

Viyanti, V., Cari, C., Sunarno, W. and Prasetyo, Z.
Students' Argumentation Skills: Does It Need Strengthening?.
DOI: 10.5220/0008410802580266
In *Proceedings of the 2nd International Conference on Learning Innovation (ICLI 2018)*, pages 258-266
ISBN: 978-989-758-391-9

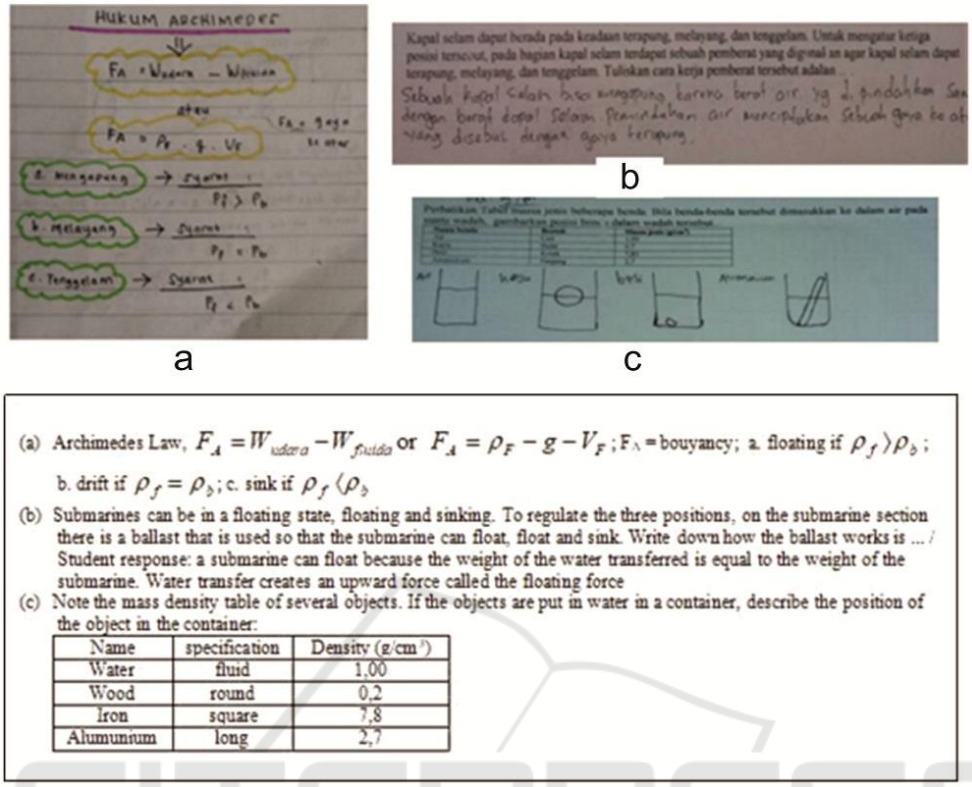

Figure 1: The example of students' note.

The complexity of learning can be overcome by strengthening argumentation skills in order to expand understanding of facts and concepts, where the emphasis is on cognitive processes. Learning that focuses on strengthening the skill of arguing produces unlimited impact leads to complex and challenging pedagogical changes. Strengthened argumentation skills are related to what students know about knowing, not at the level of skills which needed to acquire knowledge. Strengthened argumentation skills require the ability of students to construct and evaluate scientific arguments and for scientific reasons. In addition, it requires reasoning ability to present statements regarding boundary constraints. (Cobb, 2002) sequential activities in producing argumentation as a step to observe students' conceptual understanding. (Lemke, 1990; Driver, Newton and Osborne, 2000) arguing skills play a role in education and scientific evaluation. (Sandoval, 2003; Sandoval and Reiser, 2004) arguing skills have explicitly considered the purpose of explanation, described the phenomenon in question, and used data to compile statements. (Driver *et al.*, 1994) argumentation skills help students to focus on understanding the goals of science learning by supporting their knowledge. It claim and illustrate how to know knowledge.

Based on the explanation above, students' argumentation skills need to be strengthened in a planned manner so that the production of student arguments can be monitored. Therefore, efforts should be made to improve the strengthening pattern of argumentation skills by prioritizing the preparation of informative argumentation skills instruments. The priority to strengthen argumentation skills is directed in order to prepare students to be strong and creative in solving problems. One of the efforts to strengthen argumentation skills by striving for a pattern of developing argumentation skills that can be accelerated. In order to accelerate the strengthening of students' argumentation skills, researchers have conducted a research entitle "Student Argumentation Skills: Does it need to be strengthened?. The purpose of this study was to analyse the construction of the decomposition of quality argumentation production in strengthening argumentation skills using the argumentation skills assessment instrument. Strengthened argumentation skills have an impact on:

(1) skilled students submit statements (Kuhn, Clark and Huang, 2000) and (2) understanding of the concept is based on quality argumentation (Kuhn and Reiser, 2005). Strengthening argumentation skills requires consistency in the production of quality arguments that are acceptable.

2 METHOD

The method used in this research is descriptive survey method. The research population was high school students in the Bandar Lampung City Region, with a sample of 50 class XI students who had received fluid material. Data was collected using reasoned multiple choice tests and interviews. The multiple choice test models describe the student's initial statement while the reason used in the second pattern is the reason that can support the statement in the first pattern. Strengthening students 'argumentation skills is assessed and analysed from the choice of students' answers in the first patter. And their reasons in is the second pattern. Argumentation skills have been strengthened if students have the correct conception indicated by the statement and the right reasons. This test consists of 20 items. Interviews are used to clarify and strengthen students' answers. Interviews are conducted after students complete the test. The indicators of strengthened argumentation skills are shown in Table 1.

Table 1: Learning indicator and item test.

Concepts of Material	Elements of Argumentation Skills	Indicators of Argumentation Skills Questions	Item Test
Archimedes principle	The Claim describes the structure / complexity of the argument	Revealing the phenomenon Establish knowledge Repair knowledge	1, 2, 3, 4, 5, 12, and 13
	Claim describes the contents of the argument	Statement with empirical evidence Describe cognitive processes Provides more than one relevant proof	6, 8, 9, 10, 11, 14 and 18
	Claim describes the nature of the reason statement	Adequacy of evidence supporting the claim Submitting several multivariate claim supporting the phenomenon Construction of conceptual understanding	7, 12, 13, 15, 16, 17 19 and 20

3 RESULTS AND DISCUSSION

Arguing skills do not occur spontaneously and are very difficult to maintain because they are related to student knowledge. The process of strengthening argumentation skills requires complex knowledge as a fact of exploring ideas about physics phenomena. This process contributes to conceptual understanding and allows students to integrate thinking skills with initial knowledge. (Von Aufschnaiter *et al.*, 2008) reveal that when students strengthen their arguments, students have taken advantage of initial experience and knowledge. In line with (Von Aufschnaiter *et al.*, 2008) statement, the argumentation skill: (1) facilitating statements to clarify goals (Osborne and Patterson, 2011), (2) modifying beliefs, expanding and deepening statements (Baker, Hope and Karandjeff, 2009) and (3) facilitating conceptual change (Chinn, 2006).

Figure 2 is an example of a problem with a settlement pattern containing three categories producing statements in the context of science (1) the structure or complexity of the argument (your statement ...), (2) the content of the argument (what do you think your statement means ...), and (3) the nature of the reasoning (why do you think that ...). This pattern influences the type and quality of arguments developed by students to determine whether students understand the theory or how well the data supports the statement. In line with research (1) (Kuhn, 1999) student knowledge can be seen from the relationship between data and statements supported by alternative frameworks; (2) (Sandoval, 2003) structured explanation patterns help students understand learning; (3) (Kuhn and Reiser, 2005) indicates that students need work patterns to produce argumentation.

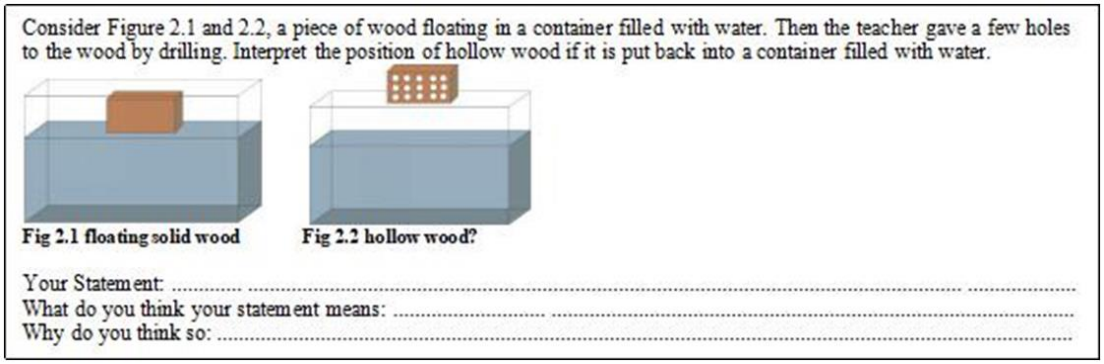

Figure 2: Examples of problems and patterns of completion.

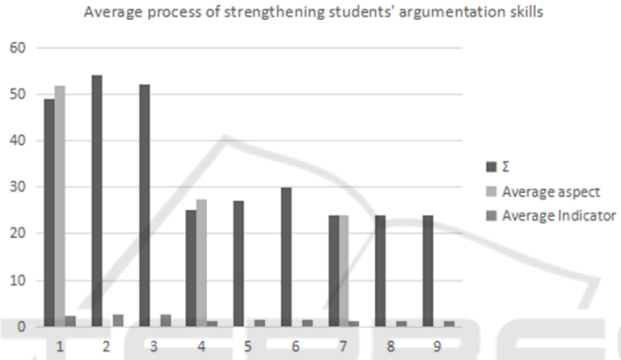

Figure 3: Distribution of the process of strengthening students' argumentation skills.

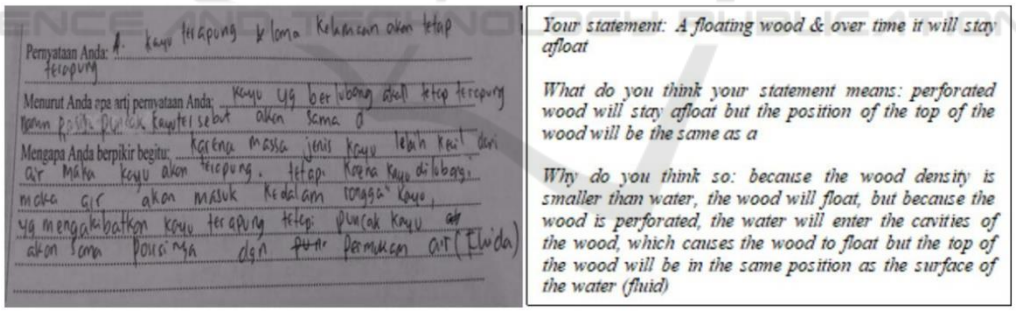

Figure 4: Example statement of student A.

Figure 3 illustrates the achievement of the process of strengthening students' argumentation skills in the material of Archimedes principle facilitated by the argumentation skills assessment instrument.

Based on Figure 3, almost all students have aspects of the process of strengthening argumentation skills. Students who have the greatest average for the argumentation production indicator describe the structure and complexity of the statement by 51.7%; 27.3% illustrates that the production of argumentation is strengthened for the content of the argument and 24.0% for production argues describing the nature of the reasoning. The elaboration example related to the achievement of the average process of strengthening argumentation skills in item number 2 is explained below.

3.1 The Argumentation Production Describes the Structure and Complexity of the Statement

Examples of problem solving Students A in producing arguments that describe the structure and

complexity of statements related to Figure 2 are presented in Figure 4.

The ability of Student A to produce a statement pattern in Figure 4 based on the problems in Figure 2 suggests strengthening the skill of arguing with patterns describing the structure and complexity of statements. The statement made by Student A is "a, floating wood & over time it will stay afloat". This statement describes the ability of students to process information implied in the problem and the ability to identify the causal factors of the problem. The statement of Student A focuses on justification and the criteria used to determine statements that arise based on knowledge as a thought process. Structured Student A statement is classified as a statement with level 1 quality level because it only includes claims and does not contain commentary reasons for the statement. That is, Students A should define the overall quality of the statement by focusing on the presence of data. And then the phenomena as an alternative statement will not stop at the statement provided in the main problem. The alternative statement that can be produced by Student A is "floating wood and over time, it will stay afloat. Wood that was not given a hole initially has a floating nature. When the wood is given a hole using a drill, the natural nature of the wood will remain attached to the hollow wood, which is floating if placed in a container filled with water. Alternative statements that should be produced by Student A illustrate the knowledge of students' cognitive knowledge. This statement is an important part of argumentation because "building knowledge are based on problems, data sources, and reasoning as objects of cognition". (Linn and Eylon, 2006) revealed that students must learn how to submit scientific claims and explore scientific knowledge

3.2 Production Arguments that Describe the Structure of the Content of the Argument

Science learning standards promoting science knowledge are not limited to explanations of phenomena but include the ability to establish, extend, and improve knowledge through cognitive conflicts and arguments. (Osborne, Erduran and Simon, 2004) revealed that data-based statements support the development of conceptual concepts. Associated with the second statement pattern produced by Student A as a science learning standard in which illustrates how the statements produced contain the structure of the content of the argument. In this study to build a pattern that describes the structure of the content of the argument assisted by the keyword "Do you think the meaning of your statement". Keywords used as a pattern to produce knowledge construction on maps based on the ability to define knowledge and potential observations of the problems presented. Keywords also help build student responses. The statement of Student A is: "Perforated wood will remain floating but the position of the top of the wood will be the same as a". The statement produced by Student A is dominated by the view of justification for the piece of information obtained from the problem. This statement is simple because it only contains: (1) statements that are not supported by justification (supporting theories or relevant articles); (2) there is no data to support the statement: the statement is not supported by two reasons; (3) the statement includes consequential reasons; the reasons include weak scientific knowledge. As a result the arguments produced by student A cannot be accepted part by a continued claim. These results are consistent with research (1) (Kuhn and Reiser, 2005) that students focus on the relationship of claims, points of view, or explanations rather than trying to explain; justification of arguments students rely on personal opinions; and (2) (Sandoval and Millwood, 2005) when students submit a reason for the statement often the reasons given do not include reasons, points of view, or explanations of the statement submitted. The second pattern of Student A's statement needs to be built in the process of strengthening argumentation skills so that it can describe the structure of the content of quality arguments.

The statement that can describe the structure of the content of the argument as a standard of learning science in order to strengthen the ability to argue is "floating wood and over time will remain afloat (describing the ability to reveal phenomena). The wood that was not given a hole before has a floating nature. When the wood is given a hole using a drill, the natural nature of the wood will remain attached to the hollow wood. Wood which is floating and if it is placed in water which is filled container (describing the ability to establish, extend, and improve knowledge). The existence of changes in the shape of objects will not affect the nature of floating objects / sinks. In floating events, only a part of the volume of the object is immersed in a container filled with water so that the volume of water that moves is smaller than the total volume of objects (reflecting the cognitive conflict process). Based on this, the wood that has been perforated by the teacher using a drill will remain floating in a container filled with water ". In the event of flooding the wood is not affected by

changes in the shape of the wood in a container filled with water (intact / perforated), provided that it meets the requirements of a floating object, that is if the object has a density less than 1 g/cm^3 (containing a thought process to produce justification from the previous statement)". When associated with statements that contain the structure of the content, the argument as a science learning standard needs to focus on the "thought process" with various forms of reasoning in science (produces alternative statement). Based on this, it takes the ability of students who are able to produce valid statement predictions (Lawson, 2003), sourced from observations of concrete problems into abstract statements in an argument (Kelly, Regev and Prothero, 2005), or use rhetoric according to reference (prove) when producing statements or acceptance of explanations of statements (Sandoval and Millwood, 2005).

3.3 Production Argumentation as a Depiction of the Nature of the Reason Statement

The truth of an argument from the perspective of the framework structure describes the nature of the reason statement. The nature of the reason statement can be produced by students in this study by using the keyword "Why do you think so". This keyword as an illustration involves accepting the reasons provided and the relevance of the reasons. As for the results of Student A's statement "because the wood density is smaller than water. And the wood will float. However, because the wood is perforated, the water will enter the wood cavities. And it will cause the wood to float but the top of the wood will be in the same position as the surface of the water (fluid)". The statement of Student A indicates that the statement has reached an accurate conclusion, indicated by Student A's opinion on the problem enough to prove the correct idea but unfortunately does not involve initial knowledge as a way to prove the statement and involve data to support the claim. The truth of an argument as a description of the nature of the reason statement requires rhetorical references that make detailed interpretation of the data by explaining how the data supports the claim. Here is seen the negligence of Student A who provide data to support his statement. The statement produced by Student A constructively includes the nature of the reason statement as a way to strengthen his argumentation skills, namely: 1) statement of the form of articulation of statements with empirical evidence; 2) relevant supporting evidence means that the data is reasonable based on initial knowledge, 3) the adequacy of evidence means whether the evidence supports the claim, 4) some claims mean whether students use multivariate claims to reveal the phenomenon, and 5) the structure of the text means that the construction assesses students' abilities. However, students have attempted to produce statements based on the phenomena presented in the problem (McNeill *et al.*, 2006) and students have tried to link and connect meaningful statements (Kelly, Regev and Prothero, 2005).

The statement that describes the construction of the nature of the reason statement as a way of strengthening argumentation skills is presented as follows: floating wood and over time will remain afloat (the ability to reveal phenomena). Wood that was not given a hole initially has a floating nature (ability to set). When the wood is given a hole using a drill, the natural nature of the wood will remain attached to the hollow wood, which is floating if placed in a container filled with water (the ability to extend and improve knowledge). The existence of changes in the shape of objects will not affect the nature of floating objects/sinks (statement of the form of the meaning of ratification of statements with empirical evidence). In floating events, only a portion of the volume of the object is immersed in a container filled with water, so that the volume of water that moves is smaller than the total volume of objects (describing the cognitive conflict process). Based on these phenomena, the wood that has been perforated using a drill will remain floating in a container filled with water "(relevant supporting evidence means that the data makes sense based on initial knowledge). In the event of flooding the wood is not affected by changes in the shape of the wood in a container filled with water. To provide that it meets the requirements of a floating object. If the object has a density of less than 1 g/cm^3 (the adequacy of the evidence means whether the supporting evidence supports the claim) then the position of the wood will remain equilibrium (floating). It is because of the two forces acting that are the force pushed up by the water and pull down (gravity). (Some claims mean whether students use multivariate claims to uncover phenomena). The pressure by the water also causes the wood to remain floating where the pressure applied has two properties. Firstly, the direction of the pressure on the surface is always perpendicular to the surface. Secondly, the pressure exerted by water increases when objects are placed in water. Based on this, hollow wood will remain floating (the structure of the text means construction assesses the ability of students to follow the organization of the argument)

Thus the nature of the reason statement produced by Student A does not take into account all the information available when producing an argument. In addition, scientific justification claims are based on the interpretation of data collected in several statements. (Chinn and Brewer, 1998) that students often failed to see patterns of data anomalies to construct statements. As a result, students "A" assume that the statement produced has contained relevant justifications including scientific knowledge, but actually the statement is not accurate because it does not coordinate claims with available data. A full explanation should be given to strengthen the students' argumentation skills which illustrate the construction of the nature of the reason statement. It contains: (a) clarification of the statement how: floating wood and over time will stay afloat at different levels, (b) a description of the statement of how the wood was not given a hole has a floating nature: When the wood is given a hole using a drill, the natural nature of the wood will remain attached to the perforated wood which is floating if it is placed in a container filled with water, and (c) an illustration of the statement how changes in the shape of objects will not affect the nature of floating objects : In a floating event, only a portion of the volume of the object is immersed in a container filled with water so that the volume of water that moves is smaller than the total volume of the object.

3.4 The Process to Strengthen the Ability to Send Arguments Strengthening Bearings Skills Process

Based on the justification of claim simple knowledge generated by Student a shows the difference between evidence for claim and explanation of the theory resulting in an alternative statement. Supposedly, a justification claim A student is able to process the purpose of the keywords provided: "Your statement", "Do you think the meaning of your statement", and "Why do you think so" join into a single statement representation. But the results show students tend to choose data from what happened as a guide to the explanation of "why it happened". In addition, students only use data when supporting certain statements even though students understand the importance of statement and data relationships.

The argument made by student A also has not shown the ability to apply students' conceptual understanding of Archimedes principles. It produces arguments that can be used to explain phenomena in accordance with these principles. Overall Student A has not been able to map the development of the skills to produce his argument. This shows that Student A does not understand the structure and purpose of the argument to be achieved. Student's "A" statement results correspond to previous research that students often produce simple arguments (Sadler, 2006) and do not attempt to support statements with data (Sandoval and Millwood, 2005) or try to show why statements are acceptable (Kuhn and Reiser, 2005). Related to this, the way to strengthen the argumentation skill is: (a) to raise and criticize the problem to produce a statement, (b) to direct the statement according to the results of the interpretation. The other effective strategies need to be raised, namely: adding and using case-based questions, submitting clarification statements, interpreting, using a sequence of statements based on problems and data interpretation. As a result, when students are specifically asked to produce arguments in this form, they tend to produce confusing arguments because the loss of elements strengthens the argument.

The process of strengthening students' arguments using the skill assessment instrument argues focusing on justification considerations and criteria for developing argumentative skills indicators. This indicator is used to determine whether or not the information in the statement or whether the statement contains scientific reasons. The diversity of perspectives that can be assessed from this argumentation skills assessment instrument has provided a way to strengthen students' argumentation skills. Strengthening the skills of argumentation focused on the components of evidence proving that students tend to rely on limited information to justify statements. This study shows that students tend to focus on statement relationships rather than suggesting statements (McNeill *et al.*, 2006). Students tend to draw conclusions based on experience and practical theory (Kuhn and Reiser, 2005). In addition, students submit statements that do not use data to support the statement (Sandoval and Millwood, 2005). This research focuses more on the "thinking process" where students tend to rely on reasoning. Students compete to produce quality arguments (Lawson, 2003), from concrete observations to more abstract ideas (Kelly, Regev and Prothero, 2005).

The learning environment greatly influences learning objectives to strengthen argumentation skills. This is a complex challenge for researchers when researchers apply an argumentation skill assessment instrument in a learning environment that is not familiar with argumentation skills. Related to

this, thinking skills are needed that must be trained periodically so that students are able to develop and assess quality arguments. Some experts suggest how to train thinking skills related to strengthening argumentation skills in the learning process: 1) train students to solve problems (Norman, 1980; Hutchins, 1995). The problem in question is able to provoke students to collect, organize; understand information related to problem solving (Reiser *et al.*, 2001). (Norman, 1980), when cognitive knowledge is used to manipulate information, cognitive knowledge is a means to interact with problems. The quality of the test argument students have (a) sufficient data in guaranteeing a claim, (b) coherent explanation for a phenomenon (Sandoval, 2003), and (c) combined according to data references (Sandoval and Millwood, 2005) synthesizing structure, and content.

Regarding content, this development instrument offers a pattern of reinforcement so that students produce arguments to uncover phenomena using relevant theories, such as Archimedes' principles, and ensure the statements produced are connected with data. Explicitly a good instrument is capable of forcing students to produce quality statements and how well supported by data (Sandoval, 2003; Sandoval and Reiser, 2004). The instrument helps students focus on understanding knowledge and ways of supporting statements (Driver *et al.*, 1994). However, further research is needed to analyze the relationship between the structure and relevance of statements, the adequacy and accuracy of statements and learning strategies that strengthen computer-assisted argumentation skills.

4 CONCLUSION

Students' have the skills to submit statements that focus on justifying the content or how well the statement component supports the understanding of students' concepts. Students have also succeeded in generating arguments in response to problems related to the phenomenon of "hollow wood will remain afloat but the position of the top of the wood will be the same as wood a." The success of students involved in producing arguments facilitated by argumentation skill instruments broadly and precisely guides the thinking process of connecting relevant information to a coherent explanation, and it is also able to articulate and justify student explanations regarding why objects float and sink. The results of this study illustrate the importance of strengthening argumentation skills in science. This study describes students' arguments that provide a lot of information about understanding concepts and students' ability to communicate and justify written statements. This study has also guided how to analyze student argumentation production focusing on statement structure, content, and relationships between components.

REFERENCES

Von Aufschnaiter, C. *et al.* (2008) 'Arguing to learn and learning to argue: Case studies of how students' argumentation relates to their scientific knowledge', *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, 45(1), pp. 101–131.

Baker, E. D., Hope, L. and Karandjeff, K. (2009) 'Contextualized Teaching & Learning: A Faculty Primer'. Academic Senate for California Community Colleges.

Chinn, C. A. (2006) 'Learning to argue', *Collaborative learning, reasoning, and technology*, pp. 355–383.

Chinn, C. A. and Brewer, W. F. (1998) 'An empirical test of a taxonomy of responses to anomalous data in science', *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, 35(6), pp. 623–654.

Cobb, P. (2002) 'Reasoning with tools and inscriptions', *Journal of the Learning Sciences*, 11(2–3), pp. 187–215.

Driver, R. *et al.* (1994) *Making Sense of Secondary Science: Research into Science Ideas*. London & New York: Routledge.

Driver, R., Newton, P. and Osborne, J. (2000) 'Establishing the norms of scientific argumentation in classrooms', *Science education*, 84(3), pp. 287–312.

Hutchins, E. (1995) *Cognition in the Wild*. Cambridge, MA: MIT press.

Kelly, G. J., Regev, J. and Prothero, W. (2005) 'Assessing lines of evidence with argumentation analysis', in *In annual meeting of the National Association for Research in Science Teaching*. Dallas, TX.

Knight, J. K., Wise, S. B. and Southard, K. M. (2013) 'Understanding Clicker Discussions: Student Reasoning and the Impact of Instructional Cues', *CBE-Life Sciences Education*, 12(4), pp. 645–654.

Kuhn, D. (1999) 'A developmental model of critical thinking', *Educational researcher*, 28(2), pp. 16–46.

Kuhn, D., Clark, D. and Huang, T. (2000) *lntellectual values: Patterns of generational and subcultural variation and their implications for values as a mechanism of cultural transmission*. Teachers College, Columbia University.

Kuhn, L. and Reiser, B. (2005) *Stude nts construc ting and defend ing evidence- based scient ific explanations*. Dallas, TX.

Lawson, A. (2003) 'The nature and development of hypothetico-predictive argumentation with

implications for science teaching', *International journal of science education*, 25(11), pp. 1387–1408.
Lemke, J. L. (1990) *Talking science: Language, learning, and values*. Norwood, NJ: Ablex Publishing.
Linn, M. C. and Eylon, B.-S. (2006) *Science education: Integrating views of learning and instruction*. Handbook o. Mahwah, NJ: Lawrence Erlbaum.
McNeill, K. *et al.* (2006) 'Fading scaffolds for argumentation and explanation', *Journal of the Learning Sciences*, 15(2), pp. 153 – 191.
Norman, D. A. (1980) 'Twelve issues for cognitive science', *Cognitive science*, 4(1), pp. 1–32.
Osborne, J., Erduran, S. and Simon, S. (2004) 'Enhancing the quality of argumentation in school science', *Journal of research in science teaching*, 41(10), pp. 994–1020.
Osborne, J. and Patterson, A. (2011) 'Scientific argument and explanation: A necessary distinction?', *Science Education*, 95(4), pp. 627–638.
Reiser, B. J. *et al.* (2001) 'BGuILE: Strategic and conceptual scaffolds for scientific inquiry in biology classrooms', *Cognition and instruction: Twenty-five years of progress*, pp. 263–305.
Sadler, T. (2006) 'Promoting discourse and argumentation in science teacher education.', *Journal of Science Teacher Education*, 17, pp. 323 – 346.
Sandoval, W. A. (2003) 'Conceptual and epistemic aspects of students' scientific explanations', *Journal of the Learning Sciences*, 12(1), pp. 5–51.
Sandoval, W. A. and Millwood, K. A. (2005) 'The quality of students' use of evidence in written scientific explanations', *Cognition and Instruction*, 23(1), pp. 23–55.
Sandoval, W. A. and Reiser, B. J. (2004) 'Explanation-driven inquiry: Integrating conceptual and epistemic scaffolds for scientific inquiry', *Science Education*, 88(3), pp. 345–372.