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ONLINE LEARNING IMPACT ON STUDENTS' SCIENTIFIC ARGUMENTATION ABILITY ON THERMODYNAMICS

Dewi Priyantini[a,1,*], Supriyono Koes-H[a,2], Eny Latifah[a,3]
[a] Physics Education, Universitas Negeri Malang, Semarang Street No. 5, Malang, 65145, Indonesia
[1] dewi.priyantini.1803218@students.um.ac.id*; [2] supriyono.koeshandayanto.fmipa@um.ac.id; [3] eny.latifah.fmipa@um.ac.id
*Corresponding author

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ABSTRACT

Abstract: Scientific argumentation is a cognitive complex that requires scientific reasoning related to theory and evidence of critical thinking related to the argument. The purpose of this study is to analyze the ability of scientific argumentation on the topic of Thermodynamics in online learning. The sample in this study were 100 students of class XII at SMA Negeri 1 Pacitan who had studied Thermodynamics through face-to-face learning and online learning. Data on scientific argumentation skills were obtained through 11 two tier questions accompanied by student explanations and arguments, reliability coefficient 0.7 15 with criteria high. The assessment is based on the TAP rubric which consists of 5 aspects including claims, data, warrants, qualification and rebuttal. The results of the analysis show that the students' arguments are still low on the aspects of warranting and backing. students provide reasons not accompanied by proof of the concept of thermodynamics, but students only give opinions that they think are correct and based on the knowledge they have experienced and observed.

INTRODUCTION

Physics helps students build argumentative reasoning and problem-solving skills (Kemendikbud, 2014). Students can develop analytical skills and argue to establish scientific explanations, develop critical thinking abilities, and assess alternatives (NRC, 2011; Lee et al., 2014; Hakim et al., 2019). Argumentative reasoning is a form of scientific inquiry and literacy (Erduran et al., 2015). Students must perform argumentative reasoning with teacher direction (Mao et al., 2018). Students learn argumentative thinking by making arguments, using data to support them, and proving them using scientific norms or evidence. Building scientific knowledge requires good argumentation skills.

Scientific argumentation is the process of explaining a phenomenon through argumentative learning, where each student defends his opinion and answers to other students' opinions with evidence. In practice, students endeavor to validate between conclusions, explanations, conjectures, or other reason-based statements (Sampson & Blanchard, 2012). Reasoning in an argument involves showing why the evidence supports the statements made (Sampson et al., 2011) (Wang & Buck, 2016).

Students struggle to argue scientifically. Learning physics has not directed students to acquire problem-solving skills using evidence-based arguments (Sampson & Blanchard, 2012). This is even worse because many students struggle with thermodynamics (Foroushani, 2019). Thermodynamics studies heat and work transfer. The concept of thermodynamics studies the change in energy into mechanical motion and work, the concept of heat, the relationship between pressure, temperature, and volume (Madden et al., 2011) (Leinonen et al., 2015), and distinguishing between work done on the system and work done by the system (Wattanakasiwich et al., 2013).

Thermodynamics should help students develop excellent arguments and understand daily phenomena. (Rahman et al., 2018) used Sutopo's (2012) argumentation quality criteria to measure students' level 1 (unsupported) and level 2 (supported) reasoning (phenomenological). This research analyzes online students' capacity to argue scientifically about thermodynamics. In this study, researchers examined students' scientific arguments using Erduran and Sampson's TAP. The researcher alters the questions by adding thermodynamic-based descriptions.

METHOD

This research design used a quantitative descriptive research design. The subjects in this study were taken using *cluster sampling*. It enrolled the students of class XII MIPA 5, XII MIPA 6, and XII MIPA 7 at SMA Negeri 1 Pacitan during the academic year 2020/2021. The subjects of this study were 100 students. Data collection was using a multiple-choice test accompanied by a description of 11 questions that have been validated on Thermodynamics topic. Each of the questions in the first point students were asked to give their claims related to the problems in the problem, then at the second point students were asked to provide a description of their reasons and arguments accompanied by support for the claims given by the student, students were also asked to provide a rebuttal if it is not appropriate. The test utilized *Google Forms* and it took 90 minutes. The primary data in this research was how students give answers and scientific arguments to the questions given. The reliability of the instrument used was 0.715, with moderate and difficult questions levels. Furthermore, qualitative data was collected through interviews through to support qualitative analysis based on the findings and difficulties experienced by students during the research.

The questions used were adapted from the Instruments Wattanakasiwich, et al (2013), Serway Jewett, (2010) and Gioncoli, Douglas C. (2014). The following is a description of the sub-topics and number of questions on the instruments used.

Table 1. Table of sub topics and question numbers

Thermodynamics Concept	Question Number
Ideal Gas Concept	1, 7
Work on Thermodynamic Concepts	2, 9
Temperature and heat transfer	3.4
Application of the First Law of Thermodynamics	5, 6, 8
Application of Entropy and the Second Law of Thermodynamics	10, 11

This study refers to the argumentation indicator by Toulmin (2013) which consists of *data* (D), *warrant* (W) , *backing* (B) , *claim* (C) , *qualifier* (Q), and *rebuttal* (R). The following table describes the components and descriptions of TAP:

Table 2. Toulmin Argumentation Pattern (TAP)

Component	Description
Data	Facts, based on facts, are used to prove *claims*
Claim	Statements used to answer the problem (hypothesis)
Warrants	Describe the relationship between *data* and *claims*. Explain how *data* supports *claims*
Backing	Assumptions that support the receipt of *warrants*
Qualifiers	Shows certainty and uncertainty in arguments
Rebuttals	Disclaimer or statement used when the *claim* is not accepted

The framework used to assess the level and characteristics of students' argumentation skills in this study is as follows.

Table.3 Levels and Characteristics of the TAP Argument

Level	Characteristics of Argument
Level 5	Extensive argument with more than one *rebuttal*
Level 4	Argument with a *claim* accompanied by a clear identification of the *rebuttal* Arguments can also consist of multiple *claims* and *counter-claims*
Level 3	Arguments consisting of a series of *claims* or *counter-claims* with *data* , *warrants,* or *backing* usually accompanied by a weak *rebuttal*
Level 2	Arguments consist of *data,* multiple *claims, warrants,* or *backing* , but not accompanied by *rebuttal* With details: At Level 2B - Arguments consist of multiple *claims* supported by more than one data , *warrant* or *backing* and without *rebuttal.* At Level 2A - Argument consists of multiple *claims* backed by one *data, warrant* or *backing* and without *rebuttal*
Level 1	A simple argument consists of *claim vs counter-claim* or *claim vs claim*

(Erduran et al., 2004) (Sampson et al., 2012)

RESULTS

The preceding courses on Thermodynamics topic were conducted in a mixed way, with the first week consisting of face-to-face meetings followed by online instruction. Online education is conducted using school e-learning and WhatsApp as a communication tool between teachers and students. The teacher gave learning instructions, including the distribution of learning introductions, learning resources, student workbooks, and daily quizzes via the e-learning platform. During online learning, teachers and students conduct question and answer sessions and provide students with feedback.

Based on the outcomes of the scientific argumentation test about material thermodynamics, the following conclusions were drawn.

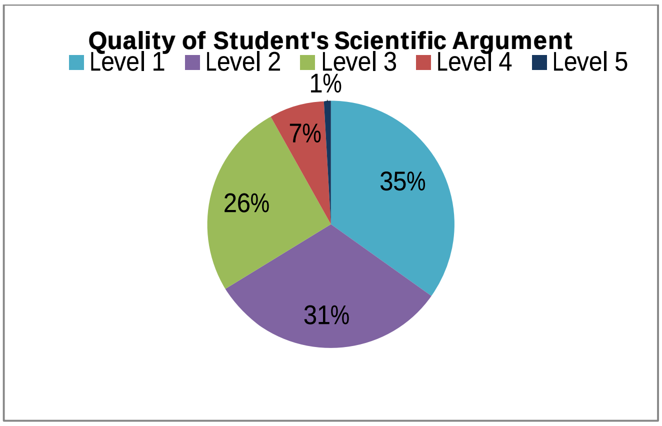


Figure 1. Quality of Students' Scientific Arguments

Data was acquired through grading based on the TAP rubric, and based on the analysis conducted, 35% of the sample's students' responses were at level 1, in which statements are made without proof or explanation. Up to 31 percent of the sample consists of pupils at level 2, whose responses include statements backed by arguments consisting of evidence and warrants or support, but no rebuttals. Up to 26% of the sample's pupils were at level 3, where they were able to provide a sequence of claims or counterclaims supported by data, warrants, or backings and weak rebuttals relating to the supplied questions. Up to 7% of the sample was at level 4, when students replied correctly and gave claims, statistics, warrants, or justifications along with a clear refutation. At this level, an argument may include many claims and counterclaims. Up to 1 percent of the sample was at level 5, with students providing assertions, statistics, and justifications or explanations pertaining to the questions asked, as well as more than one rebuttal or explanation for why they faulted alternative answer choices. At this level, the arguments presented are comprehensive and include multiple rebuttals. The average quality of student argumentation ranges from level 1 to level 3, based on the number of students who respond to questions with comprehensive and logical reasons. Based on the amount of questions, the findings for argumentation ability are as follows.

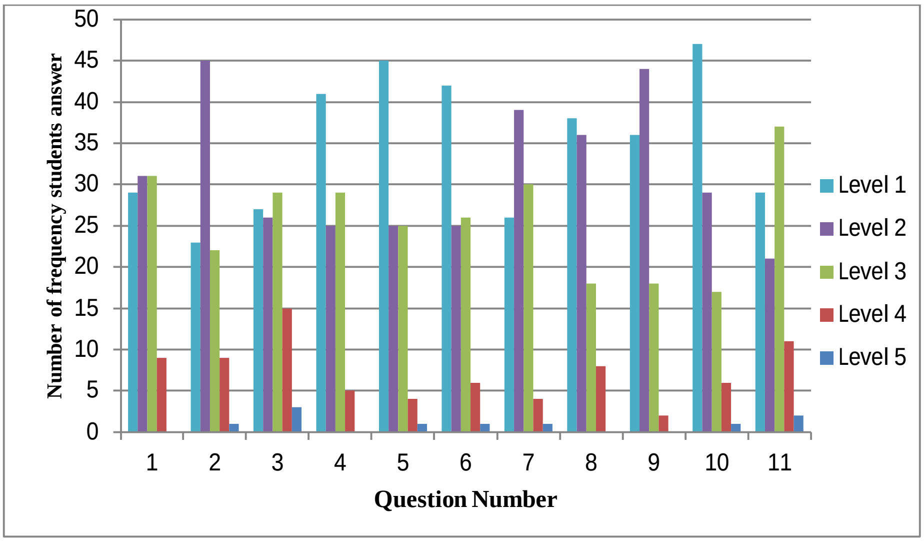


Figure 2. Distribution of students' argumentation ability answers based on the assessment rubric

Based on Figure 2, it is determined that the frequency of students with level 1 scientific argumentation skills, i.e., students who merely make assertions without offering explanations or proof, is depicted. The number of students who solely provided claims was significant and constant throughout the majority of items provided. After conducting interviews with students regarding why they did not provide reasons and evidence, the following explanations were uncovered: forgot about the Thermodynamics material, there were students who answered that they could not give arguments because they did not understand much about the Thermodynamics material, there were students whose answers included the word "maybe," there were students whose answers were uncertain and whose arguments did not connect with theory, and there were students whose answers included the word "probably." There are pupils who make arguments by reiterating the questions' words; they fall into the level 2A category. The outcomes of the study of student responses are as follows.

Work on Thermodynamic Concepts

On the topic of work on the concept of thermodynamics Students are asked to compare the initial and final pressures of the gas and the work done by the gas. The students' answers showed an average quality of argumentation of 2A, although some students were able to give their arguments up to level 5, along with a description of the questions and answers given by students.

Raka and Rani experimented with heating a cylinder filled with an ideal gas. After a while they observed that the volume did not change and the temperature increased to 3 times the initial temperature. For a moment, the two students gave their respective arguments.

Raka : the pressure also increases to 3 times the original pressure because the volume is kept constant

So the pressure is directly proportional to the temperature

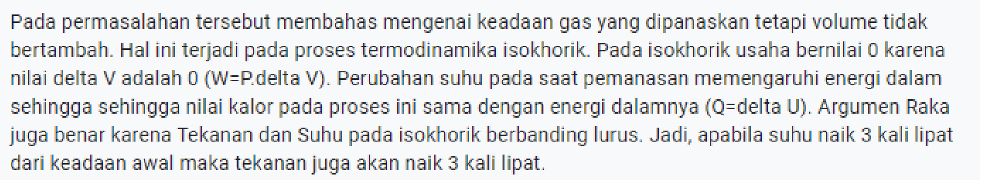
Rani : the volume does not change so the system does not do work (W= 0)

a. Which student statement do you think is true?
b. Give the right scientific explanation to support your argument!

Figure 3. Examples of Work Problems on Thermodynamics Concepts

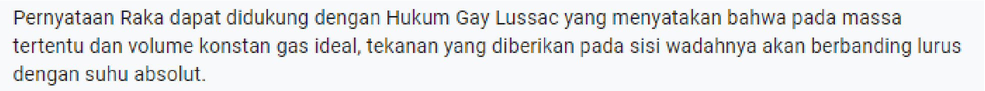
Example answer to the topic of work on the concept of thermodynamics The scientific arguments given by the students are as follows.

Student A's explanation: Raka and Rani's answers are correct



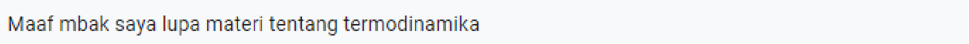
Pada permasalahan tersebut membahas mengenai keadaan gas yang dipanaskan tetapi volume tidak bertambah. Hal ini terjadi pada proses termodinamika isokhorik. Pada isokhorik usaha bernilai 0 karena nilai delta V adalah 0 (W=P.delta V). Perubahan suhu pada saat pemanasan memengaruhi energi dalam sehingga sehingga nilai kalor pada proses ini sama dengan energi dalamnya (Q=delta U). Argumen Raka juga benar karena Tekanan dan Suhu pada isokhorik berbanding lurus. Jadi, apabila suhu naik 3 kali lipat dari keadaan awal maka tekanan juga akan naik 3 kali lipat.

Student B's explanation: Raka's answer is correct



Pernyataan Raka dapat didukung dengan Hukum Gay Lussac yang menyatakan bahwa pada massa tertentu dan volume konstan gas ideal, tekanan yang diberikan pada sisi wadahnya akan berbanding lurus dengan suhu absolut.

Student C 's explanation : Raka's answer is correct



Maaf mbak saya lupa materi tentang termodinamika

Based on the figure above, Student A presents a convincing argument. Student A's response consists of multiple claims supported by warrants, evidence, and a rebuttal, resulting in argumentation of level 4. Explanation Student B belongs to level 2A; student B's responses consist of statements supported by a single piece of evidence, justification, or justification without rebuttal. Student B claims Raka's response without considering Rani's. Student C provided a response that concurred with Raka's opinion, but did not make a claim because he had forgotten the thermodynamics content. Both Raka and Rani's arguments are correct based on the scenario, where the pressure increases threefold and the system accomplishes no work. Without reading Rani's assertion, the average student in the sample agrees with Raka. Rani's viewpoint is accurate since it describes the isochoric state of constant volume.

Temperature and Heat Transfer

Questions related to temperature and displacement sub topics . Where the quality of students' arguments on this indicator are at level 1 to level 5, the following is a description of the questions and answers given by students.

Dani believes she should use boiling water to make a cup of tea. He told his friends that, "I can't make tea if I camp on a high mountain because the boiling water won't boil." His two friends argued:

Andi : Yes, Dani is right, because when you are at a certain height the water boils below 100° C, because the pressure is reduced.

Anton : Dani is wrong because water always boils at the same temperature, which is 100°C.

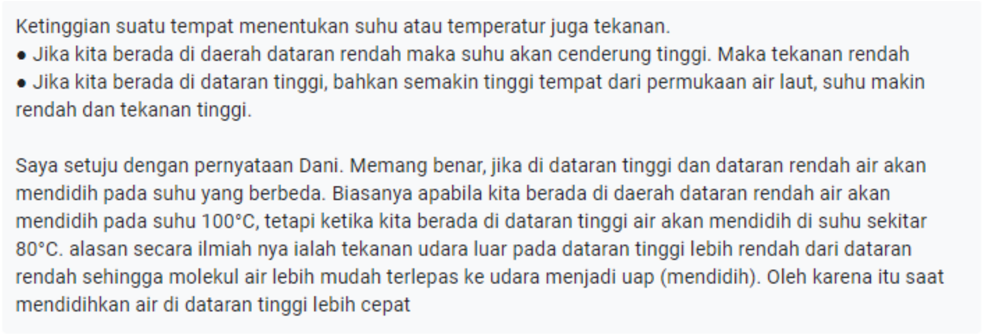
c. Which student statement do you think is true?
d. Give the right scientific explanation to support your argument!

Adaptation from: Wattanakasiwich, et all 2013.

Figure 4. Example Problem 3. Temperature and Heat Transfer

Example of answer to question no. 3 scientific arguments given by students as follows.

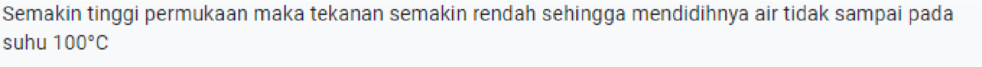
Student A's explanation: Andi's answer is correct



Ketinggian suatu tempat menentukan suhu atau temperatur juga tekanan.
- Jika kita berada di daerah dataran rendah maka suhu akan cenderung tinggi. Maka tekanan rendah
- Jika kita berada di dataran tinggi, bahkan semakin tinggi tempat dari permukaan air laut, suhu makin rendah dan tekanan tinggi.

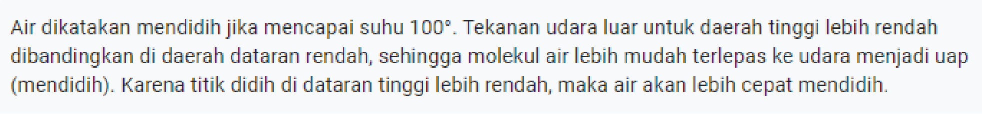
Saya setuju dengan pernyataan Dani. Memang benar, jika di dataran tinggi dan dataran rendah air akan mendidih pada suhu yang berbeda. Biasanya apabila kita berada di daerah dataran rendah air akan mendidih pada suhu 100°C, tetapi ketika kita berada di dataran tinggi air akan mendidih di suhu sekitar 80°C. alasan secara ilmiah nya ialah tekanan udara luar pada dataran tinggi lebih rendah dari dataran rendah sehingga molekul air lebih mudah terlepas ke udara menjadi uap (mendidih). Oleh karena itu saat mendidihkan air di dataran tinggi lebih cepat

Student B's explanation: Andi's answer is correct



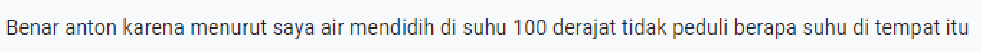
Semakin tinggi permukaan maka tekanan semakin rendah sehingga mendidihnya air tidak sampai pada suhu 100°C

Student C's explanation: Anton's answer is correct



Air dikatakan mendidih jika mencapai suhu 100°. Tekanan udara luar untuk daerah tinggi lebih rendah dibandingkan di daerah dataran rendah, sehingga molekul air lebih mudah terlepas ke udara menjadi uap (mendidih). Karena titik didih di dataran tinggi lebih rendah, maka air akan lebih cepat mendidih.

Student D' s explanation : Anton's answer is correct



Benar anton karena menurut saya air mendidih di suhu 100 derajat tidak peduli berapa suhu di tempat itu

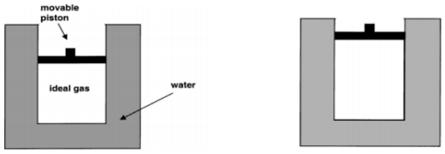
The explanation of Student A is included in the level 5 quality of argumentation. Student answers are thorough, consisting of claims followed by data, various warrants and backing, and students also provide rebuttals when presenting their arguments. Student B's response contains an explanation of the questions comprised of assertions, data, and justifications; students do not provide additional explanations of the questions. This student argument is at the 2A level. The explanations of students C and D contain misconceptions; the pupils believe water boils at 100^{o}C everywhere.

Based on their responses to questions, students tend to bolster their arguments on the grounds that altitude influences air pressure and the temperature at which water boils. However, 11 percent of respondents believed that water always boils at 100oC, demonstrating a misperception regarding thermodynamics.

Application of the First Law of Thermodynamics

Sub-topic of Application of the First Law of Thermodynamics consists of three questions. The first problem discusses the application of the concept of the First Law of Thermodynamics to gases in a closed piston , the second problem by changing the condition of the piston which allows it to go up or down. The third problem deals with changes in energy in the application of the First Law of Thermodynamics. The quality of students' argumentation is at levels 1-5, along with a description of the questions and answers given by students.

The gas in the metal cylindrical container is closed using a frictionless piston that can move up and down, no gas can enter and leave the system (State A). Then, the water container is gradually heated, and the piston moves very slowly upwards. At a certain time the heating of the water stops, and the piston stops moving when it is at the position indicated in state B the temperature of the system changes



Keadaan A Keadaan B

During the process going from state A to state B, which of the following is true:
Student A : Positive work (W+) is done on the gas by the surroundings
Student B : Positive work (W+) is done by the gas on the surroundings

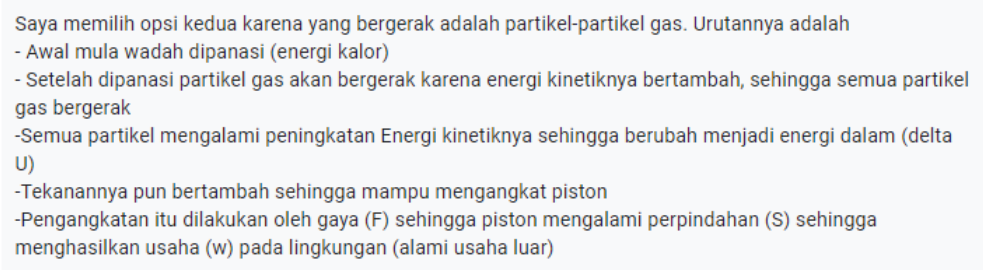
a. Which student statement do you think is true ? Mention and describe the picture briefly!
b. Give the right scientific explanation to support your argument !

Adapted from: Wattanakasiwich, et all 2013

Figure 5. Example Question 5. Application of the First Law of Thermodynamics

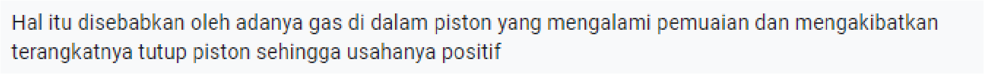
Example answer question no. 5 scientific arguments given by students as follows.

Student A's explanation: Student B's answer is correct



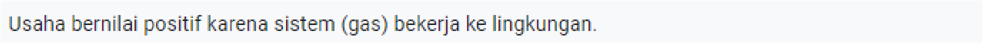
Saya memilih opsi kedua karena yang bergerak adalah partikel-partikel gas. Urutannya adalah
- Awal mula wadah dipanasi (energi kalor)
- Setelah dipanasi partikel gas akan bergerak karena energi kinetiknya bertambah, sehingga semua partikel gas bergerak
-Semua partikel mengalami peningkatan Energi kinetiknya sehingga berubah menjadi energi dalam (delta U)
-Tekanannya pun bertambah sehingga mampu mengangkat piston
-Pengangkatan itu dilakukan oleh gaya (F) sehingga piston mengalami perpindahan (S) sehingga menghasilkan usaha (w) pada lingkungan (alami usaha luar)

explanation : Student B 's answer is correct



Hal itu disebabkan oleh adanya gas di dalam piston yang mengalami pemuaian dan mengakibatkan terangkatnya tutup piston sehingga usahanya positif

Student C's explanation: Student B's answer is correct



Usaha bernilai positif karena sistem (gas) bekerja ke lingkungan.

Based on the answers given by student A, it shows the quality of the argument level 4, students provide claims, data with *warrants* , *backing* and *rebuttal* , students' answers tend to explain the state of the gas in each state before making a claim. Student B's explanation consists of claims, data and *warrants* which are included in the quality of argument level 2. The granting of *warrants* is based on the state of the gas. Student C's answer is at level 1 where the student does not provide other claims but only provides an explanation of the student's answer in the question. The average student's answers are at level 1 argumentation quality, as many as 45% of the sample only give their claims. The student did not provide an explanation as to why he supported his opinion. There are still many students who gave wrong answers, as much as 38% of the sample gave the answer that positive work (W+) was carried out on the gas by the environment . Based on this average answer, it seems that students do not understand that work can change internal energy which causes gas to push the piston up.

DISCUSSION

The analysis indicates a subpar warrant. Students' scientific arguments on Thermodynamics topic range from level 1 to level 3, with a tiny percentage reaching levels 4 and 5. First, students can argue effectively at level 5 quality. Student responses contain claims, figures, justifications, evidence, and rebuttal, but not for every question. Online learning allows students to argue utilizing previously learned concepts. According to interviews, older thermodynamics training used gadgets that let students run computer simulations and employ drawings, diagrams, and graphs. Visual simulations help improve conceptual understanding and reasoning skills (Sari et al., 2019). Mixed learning can help students support claims, evidence, and reasoning (Oktavianti et al., 2018). Students use scientific theories to explain events, which improves their understanding of the subject. Online debate participants can use evidence to buttress arguments, analyze and strengthen evidence, and confirm or amend statements (Choi & Hand, 2020).

The second poll found that students' average argumentation level is 2A, including claims, data, warrants, or support without rebuttal. Students' argument stems from question clarification. The kids' comments are mostly claims that don't explain the topics asked. Students frequently explain obstacles (Wardani et al., 2018). Argumentation helps students conceptualize. Conceptual understanding must underpin a convincing argument (Eskin & Ogan-Bekiroglu, 2013).

Third, the average student's response is still level 1 reasoning. Students repeat the question's explanation and don't expound. When queried about the responses, some students said they didn't understand thermodynamics. When asked why they used "maybe," some students indicated reluctance with the offered answer. According to research (Ain et al., 2018), students' claim-supporting beliefs are inappropriate, resulting in weak arguments. Students can debate well yet make erroneous assertions, according to research (Rahman et al., 2018). Everyday explanations are given. Students assume water boils at 100oC everywhere. According to studies (Choi et al., 2010), students' arguments are illogical, unreasonable, irrelevant, and unsupported or ambiguous.

Thermodynamics is taught face-to-face and online. The switch from direct to online schooling generated complications (Chang & Fang, 2020). (Schroder-Turk & Kane, 2020). Some students resisted the government's efforts to dismantle schools and replace them with online learning, but this boosted pedagogical innovation (Engelbrecht et al., 2020). Although most teachers create good lesson plans, it's hard to monitor and change student behavior in the near term (Chang & Fang, 2020). Students don't understand the material's content. According to study (Dumford & Miller, 2018), kids who are used to group discussions are better at learning and have less cooperation issues. This affects students' answers. Students respond based on knowledge and memory.

Students can improve their scientific reasoning by actively building arguments (Phua & Tan, 2018). Students should engage in long-term collaborative discussion and reasoning (Chen et al., 2016). Students can develop argumentation skills by defending and analyzing peer assertions online. Online learning allows students to acquire feedback progressively (Chin & Osborne, 2010), so teachers can provide evaluations with feedback and recommendations as scaffolding for assignments. Hybrid learning can include e-scaffolding to let students study independently.

CONCLUSION

This study's conclusion reveals scientific argumentation's average competency. Thermodynamics is taught online at SMAN 1 Pacitan from levels 1 to 3, but some students have argued up to level 5. Online learning can strengthen students' assertions, evidence, and reasoning. Level 2A students' arguments consist of statements, data, warrants, or backing without refutation. Providing many claims doesn't produce a problem-specific explanation. Students present explanations from the questions and make no further claims. Students' lack of thermodynamics knowledge affects their argumentative skills. Claims are not accompanied by thermodynamics proof, but students provide judgments based on experience and observation. Important to science is the ability to connect data and theory through argumentation and analysis; scientists must be able to examine their own knowledge and ideas in order to critique those of others. It is hoped that additional research will be conducted by creating learning models that enable students to participate in collaborative conversations and strengthen their scientific argumentation skills. Using Problem-Based Learning Hybrid in conjunction with E-Scaffolding is one method. Students' participation in argumentation instruction has also been advocated for a very long time.

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