JPPIPA 11(4) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

The Correlation between Critical Thinking Skills and Argumentation Skills of Biology Students: A Study across RQA, ADI, WE-ARe, and Conventional Learning

Astuti Muh.Amin[1*]

[1] Tadris Biologi, FTIK, Institut Agama Islam Negeri (IAIN) Termate, Maluku Utara, Indonesia.

Received: May 30, 2024
Revised: November 11, 2024
Accepted: April 10, 2025
Published: April 30, 2025

Corresponding Author:
Astuti Muh.Amin
astutiamin@gmail.com

DOI: 10.29303/jppipa.v11i4.7849

Abstract: The research explores the correlation between critical thinking skills and argumentation skills are still rarely found, especially in Biology lectures. Building an argument is actually a representation of students' critical thinking skills and cognitive structure. This study investigates the correlation between critical thinking skills and argumentation skills among biology students exposed to RQA, ADI, WE-ARe, and conventional teaching strategies. The samples of this research were Biology education students in the fourth semester undergoing Animal Physiology. The data were analyzed by using regression analysis. Using regression analysis, significant correlation was only found in the ADI group (R^2 = 0.192, $p < 0.05$). These findings underscore the importance of using inquiry-driven models to enhance students' reasoning abilities. The results of this research are most likely affected by the students' academic ability

Keywords: Argumentation skills; Biology lectures; Biology students; Critical thinking skills; Teaching strategies.

Introduction

The increase of the complex demands related to the working world as well as related to the open labor competition become the challenges for universities to produce competitive graduates. The 21st century skills are required by graduate students to be able competing in the global communities (Redhana, 2019). Institute of Teachers' Education should be able to foster the prospective teachers to have the skills to cope with the 21st century challenges. Critical thinking and making considerations will help people to assess credibility, to be accurate, to analzye and assess information, to make reasonable decisions, and to take responsible actions (P21 (Partnership for 21st Century Skills), 2011) . Critical thinking skills are very essential for students because these skills enable the students to be rational and to choose the best alternatives for them and also to analyze various issues they will encounter in everyday life (Salam et al., 2020). Cognitive skills, theoretical concept knowledge, and students' attitudes in learning which include creativity, collaboration, critical thinking, and communication are part of critical thinking in higher education, both theory and practicum (Gube & Lajoie, 2020).

Critical thinking is related to cognitive thinking skills (such as logical thinking, solving problems), intellectual autonomy (such as having an idea, having good reasons to support the idea) (Saputri et al., 2020). Critical thinking skills can result in good mastery of scientific development and the ability to create a pleasant learning climate (Sheybani & Miri, 2019), they can respond to and follow various developments that occur (Pradana et al., 2017). Critical thinking factors will be seen when students use their critical powers in collecting, processing, analyzing and responding to information (González-Cespón et al., 2024). Critical thinking is considered important for students' learning success. Not only does it help in processing information received through written and oral communication, but

How to Cite:
Amin, A. M. (2025). The Correlation between Critical Thinking Skills and Argumentation Skills of Biology Students: A Study across RQA, ADI, WE-ARe, and Conventional Learning. *Jurnal Penelitian Pendidikan IPA*, *11*(4), 889–899. https://doi.org/10.29303/jppipa.v11i4.7849

also improves the quality of the language produced logically and naturally (Amin, Karmila, et al., 2023). Critical thinking skills require various reasons and clear information to be synthesized until the information can be filtered and accepted perfectly(Amin & Adiansyah, 2018). A good critical thinker is skillful at articulating, analyzing, and evaluating arguments (Harrell, 2015; Lutfiyah et al., 2019). It requires precision to identify the information that really supports or disproves an argument (Kadayifci & Celik, 2016; Silitonga et al., 2020). The research conducted by Witzig showed that the process of negotiation and discussion of arguments starts from a critical reflection on the existing values and opinions (Witzig, 2014). The application of critical thinking in Biology learning provides an opportunity to develop analytical, inductive and deductive thinking skills to solve fundamental problems related to events (Ristanto et al., 2020).

The researches explore the correlation between critical thinking skills and argumentation skills are still rare, especially in Biology lectures. The research conducted by Hasanah on the students of Kharisma Bangsa Senior High School, Tangerang Selatan, Indonesia, showed that critical thinking skill had a contribution of 32.8% toward argumentative writing ability (Hasanah, 2015). There is a correlation between communication skills and digital literacy with critical thinking skills (Amin, Adiansyah, et al., 2023). By knowing students' thinking abilities, educators have considerations in delivering the learning process. Students who have these skills will be able to connect, manipulate, and transform their knowledge and experience to adapt to 21st century situations and competition (Haritani et al., 2021). Critical thinking skills influence the decision-making process related to real-world problems (Butler et al., 2017). The use of logic and critical thinking had an effect on the students' delivery of arguments (Faize et al., 2018). There was a significant correlation between argumentation skills and critical thinking skills (Kadayifci & Celik, 2016).When students use their critical thinking skills, it will affect their generic science abilities (Izetbigovic et al., 2019). It is important that this skill be developed in the learning process, because it can improve the students' concept gaining in Biology (Lustyantie et al., 2022).

Several previous research results have shown that the argumentation skills and the critical thinking skills of biology students still need to be empowered in the classroom learning. According to Roviati, biology students still had little knowledge of scientific arguments, and the quality of the arguments they produced was still relatively low (Roviati et al., 2017). The results of the observation on a learning conducted by Ariyati showed that many students still had difficulties in the problem solving related to everyday life (Ariyati, 2015). This is due to the negative effects of a series of learning activities that do not train the students' critical thinking skills. The level of the Biology students' critical thinking skills is still not well developed (Amin, 2017). The students are limited to searching for information, expression ideas, expressing disagreements,while supporting and giving clarifications are absent (Hasnunidah et al., 2020).

An enjoyable learning atmosphere will provide the students the opportunity to show courage in expressing their opinions, performing in public area and writing essays without the fear of being criticized by other students. Lecturers should develop their skills in designing an effective learning activity to improve the students' learning results (Rodzalan & Saat., 2015). The pedagogical competence of the teachers and lecturers to support the process of argumentation, such as questioning skill, answering skill, and giving responses to questions and statements needs to be intensively trained (Ramli et al., 2017). The traditional approach that emphasizes on the memorization or application of simple procedures will not able to develop the students' critical thinking skills or independence (Zubaidah, 2016).

Active, innovative and meaningful teaching strategy that can be used alternative strategies to increase the students' critical thinking skills and argumentation skills are RQA (Reading, Questioning, and Answering), ADI (Argument-Driven Inquiry), WE-Are (Warm-up, Exploring, Argumentation, Resume). The advantage of RQA teaching strategy is to improve the students' reading habit, which is still quite low. The implementation of RQA teaching strategy improves the students' learning activities (Rahmawati, 2014), one of which is through the application of questioning in the learning process (Suprapto, 2014). Students will trained in their reading skills, so that they can understand the ideas of reading materials (Sumampouw et al., 2016). Training the students to read analytically and critically is proven to improve the students' thinking ability (Mulyadi & Adlim, 2014).

The ADI learning model is effective in training generic science skills so that students are able to solve problems based on their abilities (Belga, 2022; Siahaan et al., 2019). The WE-ARe learning model can provide confidence and positive energy to make learning progress by having an optimistic attitude towards learning success (Amin et al., 2024). There have not been many researches investigating the correlation between critical thinking skills and argumentation skills of biology students especially in the subject of Animal Physiology by using RQA, ADI, and WE-ARe. Therefore, this correlation research will show the exact correlation and regression equation, and will show its contribution value.

This research is conducted to reveal the correlation between critical thinking skills and argumentation skills. In details, the problem of this research is formulated as follows: (1) How is the correlation between the critical thinking skills and the argumentation skills of biology students at the implementation of RQA (Reading, Questioning, and Answering) teaching strategy?; (2) How is the correlation between the critical thinking skills and argumentation skills of biology students at the implementation of ADI (Argument-Driven Inquiry) teaching strategy?; (3) How is the correlation between the critical thinking skills and the argumentation skills of biology students at the implementation of WE-ARe teaching strategy?; (3) How is the correlation between the critical thinking skills and the argumentation skills of biology students at the implementation of conventional teaching?. The results of this research are expected to provide relevant information for teachers/lecturers in empowering students' critical thinking skills and argumentation skills in the classroom. In this case, the teachers and lecturers can select the most appropriate teaching strategies to be implemented based on the stength of the correlation between critical thinking skills and argumentation skills. The results of this research are also important for curriculum developers, policy makers, education observers in an effort to improve the quality of university graduates, especially the prospective biology teachers. The results of this research may become a basis for further researchers to explore the critical thinking skills and argumentation skills.

Method

This research is quantitative correlational research. This research revealed the correlation between critical thinking skills as the predictors and argumentation skills as the criterion. This research used four different teaching, namely RQA, ADI, WE-ARe teaching strategies, and conventional teaching. It was conducted on the subject of Animal Physiology for one semester. It was conducted in biology education program at UIN Alauddin and Universitas Muslim Maros, South Sulawesi, Indonesia. The correlation between the predictor and the criterion is presented in Figure 1.

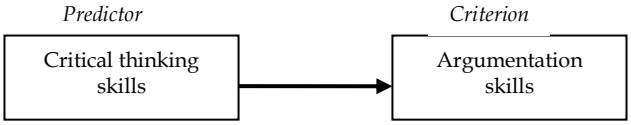

Figure 1. The Correlation between Critical Thinking Skills as the Predictors and Argumentation Skills as the Criterion

The research population was the fourth semester students of biology education program in Makassar and Maros, South Sulawesi, Indonesia, consisting of five universities with a total number of 201 students. The research samples were selected by analyzing the biology achievements and the accreditation of biology education program at the universities in Makassar and Maros, South Sulawesi, Indonesia. The results of the analysis showed that there were two equal universities; those were UIN Alauddin Makassar and Universitas Muslim Maros, South Sulawesi, Indonesia. The samples of this research were the Biology Education students of UIN Alauddin Makassar and Universitas Muslim Maros, South Sulawesi, Indonesia, consisting of 106 students. Research samples for each class with the application of the RQA teaching strategy (19 students), ADI teaching strategy (32 students), WE-ARe teaching strategy (38 students), and conventional teaching (17 students). The implementation of this research had been approved by the ethics committee of UIN Alauddin Makassar and Maros Islamic University, South Sulawesi, Indonesia.

The data collected in this correlational research covered the data of critical thinking skills and argumentation skills from each class through the implementation of RQA teaching strategy, ADI teaching strategy, WE-ARe teaching strategy, and conventional teaching. The teaching procedure of the RQA strategy was: (i) presenting the lecture topics (learning materials); (ii) preparing questions; (iii) answering questions; and (iv) presenting group assignments. While the procedure of ADI teaching strategy was: (i) identifying tasks, (ii) collecting data, (iii) producing tentative arguments, (iv) performing interactive argument sessions, (v) preparing written investigation reports, (vi) reviewing reports, (vii) revising reports, and (viii) doing reflective discussions. Meanwhile, the procedure of WE-ARe teaching strategy was the combination of the teaching procedures of both RQA and ADI teaching strategies.

The teaching procedure was delivering the topic of the lecture, reading the learning material, preparing questions, identifying tasks, collecting data, producing tentative arguments, presenting the results of group task, doing interactive argument sessions, answering questions, preparing written investigation reports, revising reports, and conducting a reflective discussion. Conventional teaching is a teaching process commonly done by the lecturer during Physiology class, characterized by the implementation of various learning methods without any district teaching model. In this case, conventional teaching was dominated by the lecturing method, and questioning & answering method.

The instruments used in this research include instruments to measure critical thinking skills and argumentation skills. The instruments had been declared valid and reliable before used for data

collection. The instruments were validated by experts, and they were also empirically validated. Expert validation consisted of content validity and construct validity. Content validity refered to the accuracy of the instruments toward the suitabiliy of the curriculum applied. Meanwhile, construct validity refered to how far the test items could measure what was supposed to be measured with the predetermined conceptual definition. Empirical validation was conducted on 50 students of semester VI (six) at biology education program at UIN Alauddin Makassar. The reliability tests of the critical thinking skills and argumentation skills were also carried out. The research instruments were declared valid and realible.

Table 1. Results of Empirical Validity and Reliability Test of Research Instrument

Research Instrument	Validity Test Result	Reliability Test Result
Critical Thinking	0.678 (all items aree valid)	0.910 (all items are consistent or reliable)
Argumentation Skills	0.688 (all items are valid)	0.815 (all items are consistent or reliable)

The critical thinking skills were measured by using validated *essay* tests. The critical thinking skill scores were obtained using the critical thinking scoring rubric developed by (Zubaidah et al., 2015), which was an adaptation of the *Illinois Critical Thinking Essay Test* and *Guidelines for Scoring. The Illinois Critical Thinking Essay Test* consisted of 5 scales (0-5). The components in critical thinking skill rubric include: (1) focus, (2) supporting reasons and reasoning, (3) organization, (4) conventions, and (5) integration. Argumentation skills were measured using validated *essay* tests. The rubric used to analyze the argumentation skills refered to the *Toulmin Argumentation Pattern* (TAP) based on the framework (Osborne et al., 2004) (Table 2).

Table 2. Assessment of Argument Skills Based on TAP

Level	Criteria
5	The argumentation presents an expanded argument with more than one clear rebuttal.
4	Argumentation shows arguments with a clear rebuttal and have several *claim* and *counter claims.*
3	Argumentation contains arguments with a set of *claims* or *counter claim.*
2	Argumentation contains arguments from one *claim* or *counter claim* with data, warrants, or backings but does not contain any rebuttal.
1	Argumentation contains arguments with a simple *claim* against a *counter claim* or a *claim* against the other claims.

The critical thinking and argumentation skill tests were given at the begining (pre-test) and at the end (post-test) of this research. The research data were also collected by observation sheets and interview. The observation sheets included the application sheet of the teaching syntax as well as the student activity observation sheets on each teachings. The instruments had been validated by the experts before used.

The data analysis of the correlation between critical thinking skills and the argumentation skills of Biology students used regression analysis with 5% significance level. Before analyzed, the data were previously tested by using *One-Sample Kolmogorov-Smirnow* test to determine whether or not the data were normally distributed. Meanwhile, the observation results related to the application of the teaching syntax, the student activities and interviews, were analyzed descriptively

Result and Discussion

The Correlation between Critical Thinking Skills and Argumentation Skills at the Implementation of RQA Teaching Strategy

The summary of the regression analysis results of the correlation between critical thinking skills and argumentation skills at the implementation of RQA teaching strategy can be seen in Table 3 and Table 4.

Table 3. The Summary of the Regression of the Correlation between Critical Thinking Skills and Argumentation Skills at the Implementation of RQA Teaching Strategy

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.091[a]	.008	-.047	6.67485

Table 4. The Anova Test Results of Critical Thinking Skills and Argumentation Skills at The Implementation of RQA Teaching Strategy

Model		Sum of Squares	df	Mean Square	F	p
1	Regression	6.661	1	6.661	.149	.704[b]
	Residual	801.966	18	44.554		
	Total	808.626	19			

The results of data presented analysis in Table 3 and Table 4 show that the F value is 0.149 with the significance value of the correlation between critical thinking skills and argumentation skills 0.704 (> 0.05). It means that there is not any significant correlation between critical thinking skills and argumentation skills at the implementation of RQA teaching.

The Correlation between Critical Thinking Skills and Argumentation Skills at the Implementation of ADI Teaching Strategy

The summary of the regression analysis results of the correlation between critical thinking skills and argumentation skills at the implementation of ADI teaching strategy can be seen in Table 5 until Table 7.

Table 5. The summary of the Regression Analysis of the Correlation between Critical Thinking Skills and Argumentation Skills at the Implementation of ADI Teaching Strategy

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.438[a]	.192	.166	9.59566

Table 6. The Anova Test Results of Critical Thinking Skills and Argumentation Skills at the Implementation of ADI Teaching Strategy

Model		Sum of Squares	df	Mean Square	F	p
1	Regression	679.029	1	679.029	7.375	.011[b]
	Residual	2854.380	31	92.077		
	Total	3533.409	32			

Table 7. Coefficient Analysis of Regression Equation between Critical Thinking Skills and Argumentation Skills at the Implementation of ADI Teaching Strategy

Model		Unstandardized Coefficients		Standardized Coefficients	t	p
		B	Std. Error	Beta		
1	(Constant)	40.328	12.976		3.108	.004
	critic ADI	.553	.204	.438	2.716	.011

The results of data analysis presented in Table 4 until Table 6 show that the F value is 7.375 with the significance value of the correlation between critical thinking skills and argumentation skills as much as 0.011 (<0.05). It means that there is a significant correlation between critical thinking skills and argumentation skills at the implementation of ADI teaching.The regression equation based on the data analyses is y = 0.533x + 40.32 with the contribution value as much as 0.192. This means that critical thinking skills have a contribution only as much as 19.2% toward the argumentation skill. Figure 2 below shows a graph ilustrating the correlation between critical thinking skills and argumentation skills at the implementation of ADI teaching strategy.

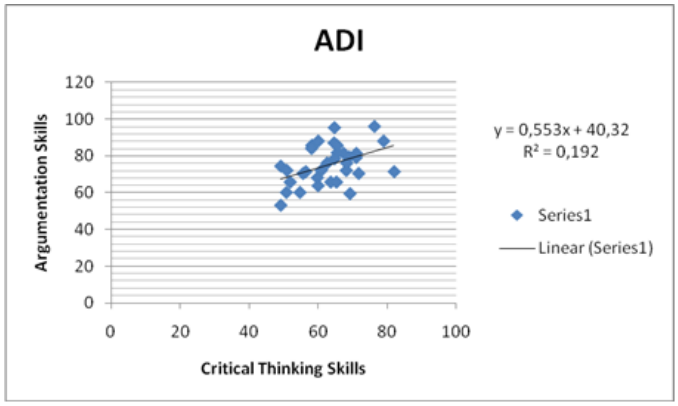

Figure 2. Graph of Regression Equation between Critical Thinking Skills and Argumentation Skills at The Implementation of ADI Teaching Strategy

The Correlation between Critical Thinking Skills and Argumentation Skills at the Implementation of WE-ARe Teaching Strategy

The summary of the regression analysis results of the correlation between critical thinking skills and argumentation skills at the implementation of WE-ARe teaching strategy can be seen in Table 8 and Table 9.

Table 8. The Summary of the Regression Analysis of the Correlation between Critical Thinking Skills and Argumentation Skills at the Implementation of WE-ARe Teaching Strategy

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.264[a]	.070	.045	6.38842

Table 9. The Anova Test Results of Critical Thinking Skills and Argumentation Skills at the Implementation of WE-ARe Teaching Strategy.

Model		Sum of Squares	df	Mean Square	F	p
1	Regression	113.424	1	113.424	2.779	.104[b]
	Residual	1510.043	37	40.812		
	Total	1623.467	38			

The results of the data analysis presented in Table 8 and Table 9 show that the F value is 2.779 with the significance value of the correlation between critical thinking skills and argumentation skills as much as 0.104 (> 0.05). It means that there is not any significant correlation between critical thinking skills and argumentation skills at the implementation of WE-ARe teaching strategy.

The Correlation between Critical Thinking Skills and Argumentation Skills at the Implementation of Conventional Teaching

The summary of the regression analysis results of the correlation between critical thinking skills and argumentation skills at the implementation of

conventional teaching can be seen in Table 10 and Table 11.

Table 10. The Summary of Regression Analysis of the Correlation between Critical Thinking Skills and Argumentation Skills at the Implementation of Conventional Teaching.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.391[a]	.153	.100	9.21428

Table 11. The Anova Test Results of Critical Thinking Skills and Argumentation Skills at The Implementation of Conventional Teaching.

Model		Sum of Squares	df	Mean Square	F	p
1	Regression	245.455	1	245.455	2.891	.108[b]
	Residual	1358.447	16	84.903		
	Total	1603.902	17			

The results of data analysis presented in Table 9 and Table 11 show that the F value is 2.891 with the significance value of the correlation between critical thinking skills and argumentation skills as such as 0.108 (> 0.05). It means that there is not any significant correlation between critical thinking skills and argumentation skills at the implementation of conventional teaching.

Observation and Interview Results

In addition to the data related to the correlation between critical thinking skills and argumentation skills, this research also collects data from observation sheets and interviews related to the implementation of RQA, ADI, WE-ARe teaching strategies, and conventional teaching. The summary of the observation of teaching syntax and student activities can be seen in Table 12.

Table 12. Observation Results of Teaching Syntax and Student Activities

Component	Teaching			
	RQA	ADI	WE-ARe	Conventional Teaching
Observation of the implementation of the teaching syntax.	Time management in the *Questioning Phase* was longer than the allocated time in the lesson plan.	Lecturer had some difficulties to stimulate the students at the phase of "*Performing Interactive Argument Sessions*".	Lecturer had some difficulties to stimulate the students to develop their critical thinking skills to produce arguments, especially in the phase of "*Preparing Written Investigation Reports* and "*Conducting a Reflective Discussion*" phase.	Lecturer provided information and learning materials directly and dominantly to students. There were very limited chance where the question & answer phase and the discussion phase to stimulate students' critical thinking skills and argumentation skills.
Observation of student activities during the implementation of teaching strategies in the classroom.	Students had difficulties to create High Order Thinking Skill (HOTS) questions.	The quality of the students' arguments in the reflective discussion phase was still simple, *argumentation contains arguments with a set of claims or counter claims (Level 3).*	Students had diifficulties to draw conclusions based on the results of the investigation and supporting evidence of arguments.	Students had difficulties in analyzing and interpreting the results of practicum based on the relevant evidence and theories. Students created arguments relying on their personal views.

The summary of the results of the student interviews related to the implementation of RQA, ADI, WE-ARe teaching strategies, and conventional teaching can be seen in Table 13.

Table 13. The Results of the Student Interviews on RQA, ADI, WE-ARe Teaching Strategies, and Conventional Teaching

No	Description of Student Interview Results
1	In RQA teaching, students had difficulties in composing high order thinking questions because they were less prepared to learn before the learning process occurred. The questions developed by the students were at the C1 cognitive level. This fact caused the students to have difficulties in formulating a quality argument.
2	In ADI teaching, students had difficulties in making strong and clear arguments. Being active in an interactive arguments session became a challenge and a new experience for them. Argument-based learning became a foreign experience. Most of the students lack confidence in giving arguments in the classroom. Students realized that to create qualified arguments required adequate critical thinking skills and concept mastery.
3	In WE-ARe teaching, students had difficulties in finding relevant evidence and theories to support their arguments. They needed more time to read and more learning resource references in order to provide arguments

No	Description of Student Interview Results
	complemented with some refutations and supporting claims. The phases of this teaching required high assimilation and accommodation skills. It required a continuous training process.
4	In conventional teaching, students had difficulties in preparing practicum reports. Previously, the students only focused on the information provided by the lecturers in learning activities. As a result, students had difficulties to relate the results of practicum activities with the existing theories. The students' ability to analyze a topic related to the learning material was still limited because the students' previous learning activities were dominated by lecturing method. This fact caused them to be less excited in the class.

The results of regression analysis of the correlation between critical thinking skills and argumentation skills in four teaching strategies show that the significance value smaller than 0.05 is only found at the implementation of ADI teaching. The results of regression analysis of the correlation between critical thinking skills and argumentation skills in the class taught by using ADI strategy obtain a regression equation of the correlation as Y = 0.533X + 40.32. This means that the contribution of critical thinking skills toward argumentation skills is as much as 19.20. The correlation between the variables of critical thinking skills and argumentation skills.

The implementation of the four teaching strategies might have been possibly affected by the students' academic ability. The stages of ADI strategy learning provide space and opportunities for explicit interactive discussions to students. They can develop their reasoning and thinking skills by developing full confidence. Collaboration between group members and supported by strong information management skills contribute to improving argumentation skills in ADI classes. The ADI learning model has tentative argumentation and argumentation sessions where students are given space to explore and stimulate thinking skills. In this session students are trained to argue, so that through this activity students' mastery of concepts is emphasized (Divena et al., 2021). The characteristics of biology education students at state university and non state universities related to the aspects of academic ability, especially higher-order thinking (C3 to C6) are still low (Amin et al., 2016). This fact causes the students unpreparedness for the implementation of teaching strategies, such as RQA and ADI teaching strategies. The initial score of the students' critical thinking skills preliminary study was low and the initial score of the students' argumentation skill was also low (Amin et al., 2017).

The quality of the students' questions in the interactive discussion (about 76.92%) was relatively low. The quality of the students' argumentation in the learning process (about 86.66%) was relatively low (Amin et al., 2017). The students were not accustomed and not ready with argumentation based teaching strategy. Those components have a great contribution toward the study of the correlation between critical thinking skills and argumentation skills. The quality of the facilities and infrastructure, such as libraries, wifi, laboratories, LCD which was still not sufficient become an inhibiting factor for the improvement of the students' academic achievements to be more standardized.

Developing an argument is actually a representation of the students' knowledge (Ramli et al., 2017). Low scientific argumentation skills indicate the students' limited ability at scientific thinking and science understanding as a whole, both from the content and context aspects. Learning is not only assumed as absorbing or transfering knowledge, but rather building or rearranging knowledge (Park et al., 2014). Students will show the correlation between knowledge and problem solving using some evidences to support their arguments, to justify their evidence, and to communicate their findings (Myers, 2015). The cognitive structure is the structure underlying an assumption and association of a concept (Cinar, 2016). Weak cognitive structures will affect the construction of new knowledge and have an effect on thinking and perception. The research conducted by Hasanah found that there was a correlation between critical thinking skills and argumentation skills (Hasanah, 2015)

The syntax of ADI teaching strategy demands high adaptability in accommodating the students' initial knowledge to actively produce arguments. The opportunity for the students to learn how to productively carry out scientific arguments is often overlooked from classroom learning activities (Ping et al., 2020). This has an effect on the lack of the students' skills in empowering their critical thinking skills to produce quality arguments. These factors cause the low contribution of the critical thinking skills toward argumentation skills in ADI class.

Based on the results of observation and interview in this research, it was found that some students experienced difficulties in generating and organizing the quality of arguments. One of the problems is that the students have some difficulties in drawing conclusion from the results of investigation. Similarly, the students also have some difficulties in analyzing and interpreting the results of the lab practice in the discussion. The arguments of students usually only contain one simple claim. The students find it hard to provide *backing* and *warrants* needed to support their written *claim* and

arguments (Bell & Linn, 2000). Arguments are used to strengthen a claim based on evidence and logical reasons (Sulisworo & Safitri, 2022). Therefore, the prerequisite to overcome these difficulties is to train the students to read analytically and critically.

The findings of this research show that the academic ability of university students is still relatively low. In general, their cognitive levels are dominantly at the level of C1 (memory) and C2 (understanding) having underdeveloped thinking analysis. The challenge that these students have to deal with in the learning process in univiersities is that they have to be able to adapt well and quickly, and they have to optimally improve their thinking level, so that they can achieve the pre-determined learning goals. The students' cognitive ability becomes one of the factors which influence the success of educators in implementing active and argument-based teaching strategies . There are a lot of factors affecting the students' academic success in universities, one of which is commitment and dedication in the teaching process (Sibanda et al., 2015).

The implementation of active and innovative teaching strategies can stimulate the increase of the correlation between critical thinking skill and argumentation skill. The effectiveness of a teaching strategy to stimulate the development of these skills is influenced by the teachers' ability in implementing the stages of each teaching strategy. In addition, it is also affected by students' assimilation and accommodation ability to the teaching strategies implemented. The results of this research are most likely due to the low human resources. Students' accommodation ability in absorbing the learning material of Animal Physiology on RQA, ADI, WE-ARe teaching strategies is still limited. Students require more time to produce qualified arguments.

Conclusion

The results of the regression analysis of the correlation between critical thinking skills and argumentation skills at the implementation of the four teaching strategies show that only at the implementation of ADI teaching is the significance value smaller than 0.05. The regression analysis of the correlation between critical thinking skills and argumentation skills in the ADI strategy class obtained the regression equation of the correlation between the two variables y = 0.533x + 40.32. The low contribution of critical thinking skills at the ADI teaching strategy and the absence of the correlation between critical thinking skills and argumentation skills at the implementation of the other three teaching strategies was influenced by the quality of *inputs* (new student candidates) with low levels of high-order thinking skills. The cognitive level of the students who are accepted at the universities every academic year is still dominated by level C1 (Memorizing) & C2 (Understanding) with not well developed critical thinking skills. It can be concluded that the correlation between critical thinking skills and argumentation skills is most likely influenced by the students' academic ability. The quality of students' argumentation is generally at level 3. Only few students have argumentation quality at level 4 and 5.

Based on the results and the conclusion of this research, it is suggested that the empowerment of the students' critical thinking skills during the teaching process be carried out by teachers and lecturers by using various ways to achieve good concept gaining. This will become the bases for the students to become independent learners and to have critical thinking skills to solve problems. It is advisable that other similar researches will be developed further using different learning courses, as well as taking into account the factors influencing students' critical thinking skills and argumentation skills. The assessment of students' argumentation skills should not only be limited to written form, but it should be accompanied by the results of description through oral arguments during interactive discussions and reflective argument sessions. In the future, researchers can conduct further research using longitudinal studies or experimental intervention models to test causality further.

Acknowledgments
Thank you to the head of the study program and lecturers at UIN Alauddin Makassar and Universitas Muslim Maros, observers and stakeholders who helped during the research.

Author Contributions
Conceptualization, A.M.A; methodology, A.M.A; resources, A.M.A; writing-original draft preparation, A.M.A; writing-review and editing, A.M.A; authors have read and agreed to the published version of the manuscript.

Funding
This research was independently funded by researchers.

Conflicts of Interest
No conflict interest.

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