Appendix 1 Development and Validation of Research Instruments

This appendix outlines the development and validation of the research instruments used in this study.

1. **DSE learning model**: Three experts evaluated its consistency using the index of consistency (IOC), giving high IOC scores (0.67–1.00). They also rated the learning steps and utility highly (4.33–5.00), and their feedback guided refinements.
2. **Lesson plans**: Seven lesson plans covered topics in biological science: (1) biome; (2) ecological succession; (3) biotic components of ecosystem; (4) abiotic components of ecosystem; (5) water pollution; (6) air pollution; and (7) the greenhouse effect. The student's progression in tests of constructing scientific explanations was included in the final step of each lesson plan. Three experts validated the lesson plans and tests, receiving IOC scores of 0.67–1.00 and high ratings (4.33–5.00).
3. **The ability in constructing scientific explanations pre-post paralleled subjective tests:** Each test consisted of 5 questions with nonspecific science contents and provided sufficient scientific information such as concepts and principles to answer the questions. The content validity evidence of the tests was verified by three experts, with an IOC score of 1.0 for all questions. The language usage and utility of the test and scoring rubrics were rated very highly (5.00) for all questions. The difficulty (p) and discrimination (d) indices of each question on the pre-test ($p = 0.33 – 0.47$, $d = 0.66 – 0.93$) and post-test ($p = 0.26 – 0.44$, $d = 0.52 – 0.88$) were within an appropriate range based on Whitney and Sabers' criteria (1970). The Cronbach's alpha reliability of both the pre-test ($r = 0.73$) and post-test ($r = 0.74$) was high.
4. **The learning achievement test:** An objective test, consisting of 31 questions on the topic of biological science. Three experts verified content validity, with an IOC score of 0.67 - 1.00. The appropriateness of the test was rated at medium to very high levels (2.67 - 5.00). The difficulty and discrimination indices of each question were within appropriate ranges ($p = 0.43 - 0.79$, $d = 0.36 - 0.39$). The KR-20 reliability of the test was high ($r = 0.90$).
5. **The semi-structured interview form**: Consisted of open-ended questions to assess students' opinions after learning with the model. The IOC scores from the three experts were 0.67 - 1.00. The appropriateness of the questions was rated at high to very high levels (3.33 - 5.00).

Appendix 2 The Students' Behaviours and Responses during Learning with the DSE Learning Model

This appendix presents a detailed summary of students' observed behaviours and verbal responses while participating in learning activities using the DSE learning model.

DSE learning model	Constructing scientific explanations levels	Observed behaviours	Examples of interview responses
Step 1: Introducing the question	Good	Students showed interest in the learning issues, with those having prior experience actively participating.	"I thought the videos in the first step were quite interesting and could be used as evidence for constructing scientific explanations." (Student A2)
	Moderate	Students considered that discussing the issues helped them assess prior knowledge and gather evidence	"I could better understand the learning topic when discussing the learning issues." (Student B1)
	Unsatisfactory	The discussion questions are lengthy and confusing.	"I'm confused about some of the questions. I don't understand the questions. The questions are long. The information provided is long too." (Student C1)
Step 2: Brainstorming to identify a claim	Good	Students who have some knowledge of the situation being used can write specific claims, eliminating impossible claims. Students who do not have enough knowledge of the situation being used as a question often choose to write all claims.	"I only selected the possible claims. I eliminated the impossible ones." (Student A2)
	Moderate		"I looked at the information provided and what I had learned." (Student B2)
	Unsatisfactory		I didn't know what was possible, so I chose all of them." (Student C2)
Step 3: Finding evidence	Good	Students searched for evidence to support their claims, often encountering conflicting information online, leading to misunderstandings and incorrect claims. Guideline questions provided by the teacher significantly improved their ability to locate accurate evidence.	"The evidence came from friends in the group was not consistent. We needed to help each other look at new information or change the websites." (Student A1)
	Moderate		"The information on the websites didn't match up. The teacher should tell me which one was correct." (Student B4)
	Unsatisfied		"The information I found didn't match my friend's. I have to ask my friend and consult the teacher." (Student C2)
Step 4: Drawing a diagram	Good	Drawing the diagram helped them provide a solid reason that connected the evidence	"This activity helped me find the reasoning component. When I drew the arrows, it let me find the

DSE learning model	Constructing scientific explanations levels	Observed behaviours	Examples of interview responses
		to the claim, and helped them assess the accuracy of the evidence and claim.	correct evidence and claim." (Student A5)
	Moderate		"It helped me identify the reason." (Student B1)
		Some students struggled with accuracy, requiring teacher support.	"I was confused about the evidence. It was very difficult for me to draw the diagram when I did not have enough information. I had to read the related information again for a better reason." (Student B2)
	Unsatisfactory		"I wanted you to provide a guideline for writing a reason." (Student C3)
Step 5: Constructing a scientific explanation	Good	Students felt this step improved their ability to construct explanations. They struggled with writing due to a lack of knowledge on how to combine components. Templates and teacher guidance were vital.	"My problem was arranging each component to be a sentence. But the guideline that the teacher provided helped me in writing. I mainly looked from there." (Student A1)
	Moderate		"It helped create a better scientific explanation because we had already summarized it on paper and could just write each part in order." (Student B3)
	Unsatisfactory		"I did not know how to start the sentences. I needed the teacher to explain the way to merge each component." (Student C5)
Step 6: Constructing explanations for new situations	Good	Students found the conclusion activity in the previous step helpful. However, they still required guidance from teachers to write individual explanations, which differed from the group activity they had done previously.	"I could use the knowledge from the evidence gathering step and the conclusion from the previous step to construct the explanations." (Student A2) "I needed teachers to provide the searching resources." (Student A3)
	Moderate		"I did not know how to start this activity because when I did it in a group, I could ask my friends and get help together." (Student B1)"
	Unsatisfactory	Students expressed confusion about the questions, evidence sources,	"I was confused about the question and couldn't find the information I needed. I didn't know

DSE learning model	Constructing scientific explanations levels	Observed behaviours	Examples of interview responses
		and constructing explanations. They needed help from teachers to identify the resources for searching data and assistance from their friends in constructing explanations.	what data to search for, so I needed help from my friends." (Student C1)

Overall, the steps helped students progress in constructing scientific explanations, particularly when teacher guidance addressed confusion and facilitated learning.