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Effect of Substrate and Water on Cultivation of Sumba Seaworm (*Nyale*) and Experimental Practicum Design for Improving Critical and Creative Thinking Skills of Prospective Science Teacher in Biology and Supporting Sustainable Development Goals (SDGs)

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ABSTRACT

This research aims to determine the effect of substrate and water type on the cultivation of Sumba seaworm (Nyale) and develop an authentic inquiry project-based practicum instrument on Nyale as Polychaeta to improve critical and creative thinking skills of prospective science teachers. The results of experimental research showed that the substrate of sea sand and sea coral can be used in Nyale cultivation because it can provide a higher survival rate for this organism. Cultivation without substrate causes Nyale to survive less. Sea water is needed to be used in cultivation. The development of an authentic inquiry project practicum instrument about Nyale shows that the instrument is feasible to be used in practicum to improve the critical and creative thinking skills of prospective science teachers. This research contributes well to the development of authentic science learning that can create meaningful science learning for students. This research also supports a problem solver for current issues in the sustainable development goals (SDGs).

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1. INTRODUCTION

Sumba seaworm (known as Nyale) is a marine worm that belongs to the phylum Annelida Class Polychaeta. Nyale has an important value in the culture and life of the people in Sumba, Indonesia. Nyale comes to the surface of the sea once a year and is always awaited. The appearance of Nyale is intended for the reproduction process but then at the same time the community flocks to pick it up for consumption (Pamungkas & Prihandini, 2021). In addition to Nyale which appears once a year, Sumba people recognize the existence of Nyale. Sumbe people often dig up and take Nyale for fishing bait. Taking Nyale in its native habitat continuously and in unlimited quantities will have an impact on the sustainability of its life. This condition will be a real-world problem that can be raised in learning for science students.

The authentic inquiry project practicum on Nyale is expected to be able to train the critical and creative thinking skills of prospective science teachers. Science education needs to be taught to increase critical and creative thinking skills. Many reports regarding science education have been well-developed (see **Table 1**).

Table 1. Previous reports on science education.

No	Title	Reference
1.	Science education for students with special needs in Indonesia: From definition, systematic review, education system, to curriculum	Maryanti *et al*. (2021b)
2.	Family as an educational environment that can provide science education for children with special needs.	Maryanti & Asjjari (2022)
3.	Analysis of Science Education Curriculum for students with Special Needs in Special Schools: the curriculum of 2013	Nursaniah (2023)
4.	How to calculate bibliometric using VOSviewer with Publish or Perish (using Scopus data): Science education keywords	Al Husaeni & Al Husaeni (2022)
5.	Science education research methodology: A case study investigating the correlation between construction, safety, accident, and the effectiveness Construction Industry Development Board (CIDB) Green Card Training Program.	Wahab *et al*. (2023)
6.	Bibliometric analysis for understanding "science education" for "student with special needs" using VOSviewer	Nursaniah & Nandiyanto (2023)
7.	Counseling guidance in science education: Definition, literature review, and bibliometric analysis	Solehuddin *et al*. (2023)
8.	Computational bibliometric analysis of English research in science education for students with special needs using Vosviewer	Sukyadi *et al*. (2023)
9.	Sustainable development goals (SDGs) in science education: Definition, literature review, and bibliometric analysis	Maryanti *et al*. (2022b)
10.	A bibliometric analysis: research trend of critical thinking in science education	Misbah *et al*. (2022)
11.	Research Trends of Mental Models and Opportunity in Science Education: A Bibliometric Analysis	Ashel *et al*. (2023)
12.	A Computational Bibliometric Analysis of Science Education Research Using Vosviewer	Maryanti *et al*. (2023)
13.	Sustainable Development Goals (SDGs) in Science Education: Definition, Literature Review, and Bibliometric Analysis	Maryanti *et al*. (2022a)
14.	Analysis of curriculum for science education for students with special needs in vocational high schools	Maryanti *et al*. (2021a)

Science invites students to continue to adapt to any conditions, think flexibly, and be able to think critically and creatively in questioning and answering various problems in science (Aktamis & Yenice, 2010). To be able to train critical and creative thinking skills in science

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learning, especially for prospective science teacher students, it is necessary to develop learning that is integrated with practice. Practicum in the learning process must be developed not only to verify the theory learned but also must contextualize the learning that has been received. Thus, it becomes meaningful for their lives (Anstey, 2017; Sanchez-Muñoz *et al*., 2022).

Previous research on marine worms (Polychaeta) has been carried out in various regions. Research Pamungkas and Prihandini (2021) found that Wawo worms found in Maluku waters are multispecies and have a relatively wide geographic distribution. Wawo worms live on rocky shores around the tropics. The species richness of this animal is still poorly studied except for nereidida, while other Wawo species are still unidentified. This study emphasizes the need for more research related to marine worms including taxonomy, fauna, and molecular research. Other studies have also shown that marine worms have many benefits for human life such as as an indicator organism of marine pollution (Belan, 2004; Giangrande *et al*., 2005), as the main prey of fish, and as bait for fishing. Thus, it becomes a side target species of fishermen (Younsi *et al*., 2010).

The purpose of this study was to determine the effect of substrate and water type on the cultivation of Nyale and develop an authentic inquiry project-based practicum instrument on Nyale (Polychaeta) to improve the critical and creative thinking skills of prospective science teachers. The novelties of this study are (i) cultivation using Nyale seaworms and (ii) developing a practicum by integrating the results of this experiment into the learning process in the classroom by using an authentic inquiry project that combines 2 levels of inquiry models, real word applications and hypothetical inquiry. This research also supports a problem solver for current issues in the sustainable development goals (SDGs), as reported elsewhere (see **Table 2**).

Table 2. Previous studies on SDGs.

No	Title	Reference
1.	Low-carbon food consumption for solving climate change mitigation: Literature review with bibliometric and simple calculation application for cultivating sustainability consciousness in facing sustainable development goals (SDGs)	Nurramadhani *et al*. (2024)
2.	Smart learning as transformative impact of technology: A paradigm for accomplishing sustainable development goals (SDGs) in education.	Makinde *et al*. (2024)
3.	The relationship of vocational education skills in agribusiness processing agricultural products in achieving sustainable development goals (SDGs)	Gemil *et al*. (2024)
4.	The influence of environmentally friendly packaging on consumer interest in implementing zero waste in the food industry to meet sustainable development goals (SDGs) needs	Haq *et al*. (2024)
5.	Sustainable packaging: Bioplastics as a low-carbon future step for the sustainable development goals (SDGs)	Basnur *et al*. (2024)
6.	Implementation of sustainable development goals (SDGs) no. 12: Responsible production and consumption by optimizing lemon commodities and community empowerment to reduce household waste	Maulana *et al.* (2023)

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Table 2. (continue) Previous studies on SDGs.

No	Title	Reference
7.	Analysis of the application of Mediterranean diet patterns on sustainability to support the achievement of sustainable development goals (SDGs): Zero hunger, good health and well-being, responsible consumption, and production	Nurnabila *et al*. (2023)
8.	Efforts to improve sustainable development goals (SDGs) through education on diversification of food using infographic: Animal and vegetable protein	Awalussillmi *et al.* (2023)
9.	Safe food treatment technology: The key to realizing the sustainable development goals (SDGs) zero hunger and optimal health	Rahmah *et al*. (2024)
10.	Analysis of student's awareness of sustainable diet in reducing carbon footprint to support sustainable development goals (SDGs) 2030.	Keisyafa *et al*. (2024)
11.	Prototype of greenhouse effect for improving problem-solving skills in science, technology, engineering, and mathematics (STEM)-education for sustainable development (ESD): Literature review, bibliometric, and experiment	Solihah *et al*. (2024)
12.	Trends and networks in education for sustainable development (ESD): A bibliometric analysis using vosviewer	Rasuman *et al*. (2024)
13.	Efforts to enhance sustainable consciousness and critical thinking in high school students through learning projects	Purwaningsih *et al*. (2023)

2. LITERATURE REVIEW

2.1. Overview of the Seaworm (Polychaeta)

Seaworms are one type of invertebrate animal that belongs to the annelid phylum and has a characteristic body shape resembling an arrangement of rings, bracelets, or segments. The body of seaworms is segmented and covered by a thin and moist cuticle (Asnawi, 2018; Shofiya *et al*., 2021; Windarto *et al*., 2023). Marine worms live in tidal habitats with sandy, muddy, or sandy loam or coral substrates. Marine worms have a relatively short life cycle and strong reproduction play the role of secondary consumers in the sea and can purify deposits by converting organic matter through feeding behavior (Kim *et al*., 2017). Some types of marine worms are considered indicator organisms of marine pollution (Belan, 2004; Giangrande *et al*., 2005), as the main prey of fish, and bait for fishing and thus become the side target species of fishermen (Younsi *et al*., 2010).

Seaworms are economically valuable as they are used as fishing bait as well as food supplements in aquaculture. Some species of marine worms in the Polychaeta class are used as food components due to their positive effects on shrimp reproduction (Meunpol *et al*., 2005) and high levels of polyunsaturated fatty acids (Chen *et al*., 2020). In fresh, chopped, or powdered form, marine worms are utilized in making feed for tiger and king prawns because they can increase growth with a protein content of 56.29 and fat of 11.32% (Rachmad & Yuwono, 2000). Nelce Mailoa *et al*. (2020) explained that seaworms have protein content ranging from 10.55% to 700.05% and iodine content which is good for growth, immune system, and fetal growth.

Waters of Lombok, Sumba, and Ambon reported that four types of polychaete marine worms show swarming phenomenon, namely Eunice siciliensis, E. viridis, Licydice collaris, and Dendronereides heteropoda. The people of Sumba are familiar with Nyale, which is a type of

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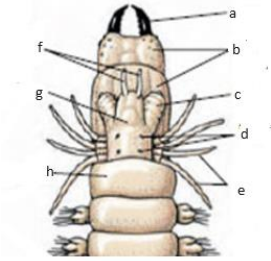
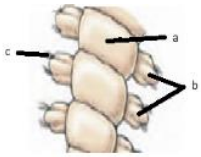
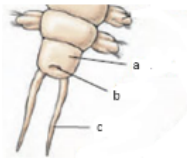
marine worm that is an invertebrate animal in the Annelida phylum, which is a biological resource found in the coastal waters of Sumba. Nyale has great potential not only as one of the natural resources but also as an important meaning for the people of Sumba. Nyale by the people of Sumba has a high cultural value that is celebrated every year by flocking to pick up Nyale which is used as food. Nyale has a meaning of fertility and abundance of harvest for the people of Sumba. In addition, the people of Sumba also recognize the existence of Nyale which is used as fishing bait. Seaworms found in Sumba waters belong to the Polychaeta class.

2.2. Morphologi Polychaeta

Table 3 shows the morphology of Polychaeta. Broadly speaking, the body of seaworms (Nyale, Polychaeta Sumba) consists of 3 parts, namely the head, trunk, and Pygidium. The head consists of 2 parts, namely the prostomium and peristomium. The prostomium is equipped with a palpus, antennae pharynx, and several tentacles. The trunk is composed of recurrent body segments with parapodia and chaeta (bristles). Parapodia and chaeta play an important role in the movement in Polychaetes. The pygidium is the posterior end with a conical or broadly rounded shape that houses the anus (Bakken & Wilson, 2005).

Table 3. Morphologi Polychaeta.

No	Parts	Figure	Description
1	Head		a. Jaw b. Pharynx c. Palp d. Eyes e. Cirri f. Prostomial tentacles g. Prostomium h. Peristomium
2	Trunk		a. Segmented b. Parapodia c. Chaeta
3	Pygidium		a. Pygidium b. Anus d. Cirrus

2.3. Repruduction of Polychaeta

Figure 1 shows sexual reproduction in Polychaeta. Polychaetes reproduce through asexual and sexual reproduction. Asexual reproduction is done through binary division by separating the posterior and anterior body parts and by budding. In binary division, the anterior part of the body will regenerate into posterior segments and pygidium while the posterior part will regenerate into anterior segments and head region. The budding polychaeta will secrete clones from the posterior end which then detach and crawl away. Sexual reproduction is done by releasing eggs and sperm cells into the water because this animal is dioecious. The fertilized egg will develop into a trochophore and then metamorphose for hours or even weeks until it becomes a juvenile. A typical way of reproduction in polychaeta is also known as epitoky where this animal modifies its body into a swimming body or epitoky (Nesto, 2018).

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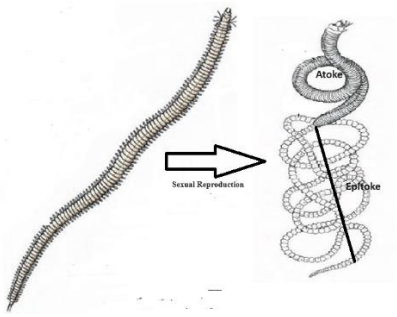

Figure 1. Sexual Reproduction of Polychaeta.

3. METHODS

This research was conducted in two stages, namely (i) the experimental research stage to see the effect of substrate and type of water used in the cultivation of Nyale and (ii) research and development with ADDIE to develop practicum instruments based on Authentic inquiry projects about Nyale (Polychaeta) to improve critical and creative thinking skills of prospective teachers.

3.1. Experimental research stage

This research was conducted in the laboratory of one of the private universities on Sumba Island. The research design used a completely randomized design. Each treatment unit used a 30x30x30 cm aquarium container and 30 Nyale were stocked. The feed used was natural feed from sand and the water used was from the sea (see **Table 4**).

Table 4. Results of Seaworm Cultivation

No	Title	Description	Ref
1	Pengaruh substrat yang berbeda terhadap pertumbuhan biomassa cacing laut (*Nereis sp*)	**Tools and materials:** Seaworms (*Nereis sp*), sand substrate, seawater, coconut pulp feed, basin with a diameter of 50cm, thermometer, pH meter, analytical scales, connecting pipes and water pumps, hoses, and aeration. **Research Design:** Using a completely randomized design with 3 treatments 1) white sand substrate; 2) black sand substrate; and 3) black sand substrate mixed with white sand. Each unit was sown with 5 worms. **Research procedure:** - Preparation of tools and materials - Acclimatization for 1 week - Set up the respective treatment containers by filling the substrate. - Seawater was supplied with a water pump to the container and flowed into the experimental unit. - Seaworms were collected from nature (Salo village) with the same size and weighed. - Each unit consisted of 5 worms The feed used was coconut pulp given twice a day at a dose of 20% of body weight. - The water temperature was 27-30 ^{0}C with a salinity of 28-32 ppt and pH 6-7. **Results:** All types of substrates tested were recommended as substrates in the cultivation of marine worms (*Nereis sp*). black sand substrate gave relatively better results for the survival of *Nereis sp* worms, while white sand substrate gave relatively good results for absolute growth and specific growth rate of *Nereis sp* worms.	Asnawi *et al.* (2018)

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Table 4 (continue). Results of Seaworm Cultivation

No	Title	Description	Ref
2	Effect of substrate media on the growth, amino acids, and fatty acids profiles of the marine worm (*Nereis virens*)	**Tools and materials used:** Marine worms (*Nereis virens*), 30 L plastic container, seawater, silt sand, clay mud, mangrove mud. **Research Design:** Using a completely randomized design with 3 treatments (1. Silt sand substrate, 2. Clay mud, and 3. Mangrove mud) with a thickness of 8 cm. **Working Procedure:** - The worms came from the marine science technopark in the growth phase (2-3 months) with an initial weight of 0.15-0.5 g. - Plastic containers were filled with substrate according to the treatment and placed 45 worms. - The seawater came from a reservoir sterilized with 10-ppm chlorine and neutralized with 5-ppm sodium thiosulfate. - Feed was provided in the form of powdered artificial feed with 40% protein content at 5% biomass. - Feed was given when the water level was only 1 cm high. - Water quality included temperature 28-31 ^{0}C, DO, 5-6.5 mg L^{-1}, pH 7-8.4, and salinity 29-31 ppt. **Results:** Mass-cultured marine worms on mangrove mud substrate had better absolute weight, survival, and growth rate values compared to worms' mass-cultured on clay and silt sand mud substrate. Worms on mangrove mud substrate contained 46-ppm methionine and 8.15 EPA.	Windarto *et al*. (2023)
3	Nutritional value and growth performance of seaworms (*Nereis sp*) fed with *Hermetia illucens* maggot flour and grated coconut (*Cocos nucifera*) as natural feed	**Tools and Materials used:** *Nereis sp*, mangrove sand, seawater, maggot flour, grated coconut, 30-L plastic container, and mangrove sand substrate. **Research Design:** This is an experimental study with a completely randomized design. There were 4 treatments with 3 replicates. Treatment 1: using 50% maggot meal, 50% shredded coconut; treatment 2: using 75% maggot meal, 25% shredded coconut; treatment 3: using 25% maggot meal, 75% shredded coconut; treatment 4: 100% maggot meal and treatment 5: 100% shredded coconut. **Research Procedure:** - Prepare tools and materials - The beach mangrove sand substrate was washed thoroughly with a recirculation system. - The container was filled with a 10 cm high substrate with a water level of 3 cm. - Seawater used comes from a reservoir that has gone through the stages of sterilization with 10 ppm chlorine and neutralization of 5-ppm sodium thiosulfate. - Two-month-old *Nereis sp* (0.20-0.22 g) were reared in containers with each container containing 100 worms. - Feed was given in the morning and evening at the rate of 5% of biomass. - Feeding was done after lowering the water level by about 1 cm. **Results:** The best treatment to support the cultivation was the treatment with 100% maggot flour feeding.	Herawati *et al*. (2020)

The first experimental design with the treatment of substrate effects with treatments

(i) Using a 10 cm thick sea sand substrate, and 100% seawater

(ii) Using small coral with a thickness of 10 cm and 100% seawater

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(iii) Using a mixture of 8-cm sand substrate, 2-cm small coral, and 100% seawater
(iv) Container without substrate and 100% seawater

The second experimental design with water treatment

(i) Using a substrate mixture of sand and small corals with 100% seawater
(ii) Using a mixed substrate of sand and small coral with 50% seawater and 50% freshwater
(iii) Using a mixed substrate of sand and small coral with 100% fresh water.

The implementation of this research procedure is based on a literature review from previous researchers who have conducted marine worm farming with some modifications based on the original habitat of Nyale. Substrate and water according to the treatment design were included in each container. Seawater, sand, coral, and Nyale samples used were taken directly from nature located at Pero Beach, Kodi sub-district, Southwest Sumba, Nusa Tenggara Timur, Indonesia. Nyale seaworms were collected using a procedure of digging the sand to a certain depth. Nyale is then slowly pulled from the sand. Taking the worms requires the correct procedure. Thus, they do not break off.

Nyale was placed in each treatment container. In this initial trial stage, no weighing was done and the Nyale used were Nyale obtained at the time of collection without sorting due to limitations in nature during the collection procedure. Each treatment container is equipped with a filter. Thus, the water is not cloudy. Each treatment was conducted for 90 days.

3.2. Research and Development Stage

This research used the ADDIE model, consisting of five main stages. The stages of the ADDIE method are shown in **Figure 2**.

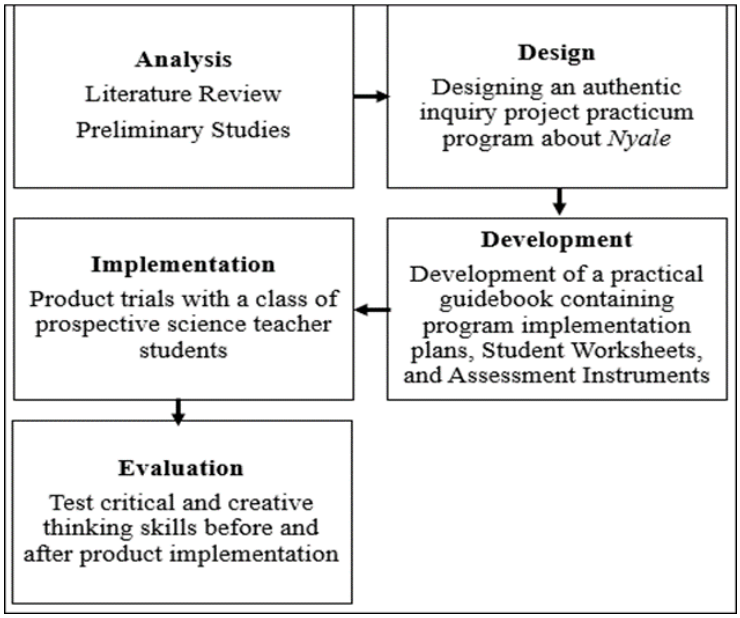

Figure 2. ADDIE Research Design

Based on **Figure 2**, the explanation of the stages of this research is described as follows:

(i) Analysis: analysis of the needs of this research was carried out in two separate stages. First, we did through literature studies related to previous research on authentic inquiry project learning. Second, preliminary studies were conducted by analyzing curriculum documents, observations and interviews of practicum implementation, and initial tests of critical and creative thinking skills.
(ii) Design: After conducting a needs analysis, we designed an authentic inquiry project practicum program on Nyale. The design stage was carried out to create a program design

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related to the practicum on Nyale which contains the linkage of Graduate Learning Outcomes in the practicum of animal anatomy and physiology courses. The program design also links the material to the topic of Nyale.

(iii) Development: the development stage was done based on the program design that was adjusted to the needs analysis. The development was in the form of developing a practicum guidebook, containing program implementation plans, student worksheets, and assessment instruments. After the development process was complete, validation was carried out by experts.

(iv) Implementation: After obtaining expert validation and revision based on expert input, the next stage was testing the product for students.

(v) Evaluation: after testing, a test was conducted in the form of a critical and creative thinking skills test before and after the application of the product. The results were then tested for validation and reliability using SPSS. Detailed information for the SPSS calculation is reported elsewhere (Fiandini *et al*. 2024; Afifah *et al*. 2022). Validation results were processed to then obtain conclusions regarding the feasibility of the instrument according to the development objectives.

4. RESULTS AND DISCUSSION

4.1 *Nyale* Cultivation

Figure 3 shows the design of the *Nyale* cultivation. *Nyale* cultivation generally used the treatment design as shown in Figure 4.3. Cultivation was carried out for 90 days by maintaining water temperature around 26-27°C and pH 7.5-8. Water quality in the cultivation of seaworms is an environmental factor that plays an important role in the success of the cultivation business. Thus, in its management, it must follow optimal standards to support the growth and survival of the test organism.

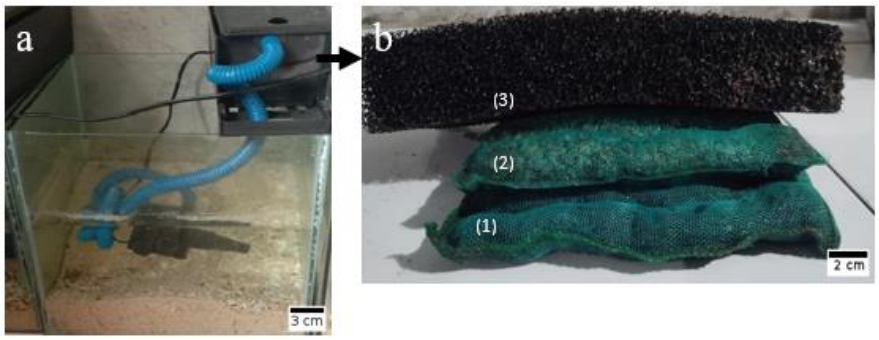

Figure 3. (a) *Nyale* cultivation design (substrate thickness 10 cm); (b) Filtration layer. In Figure (b), note (1) is a filter bag containing black stone, note (2) is the filter bag containing Gravel, and note (3) is the sponge

Table 5 describes the survival results of cultured *Nyale*. After treatment for 90 days, the number of all worms that are still alive until the final stage is calculated. The average results of absolute growth of *Nyale* worms cultivated in the laboratory. From the four treatments used in the substrate design, the survival rate either on sand substrate, small coral rock, or a mixture of both substrates has the same survival rate at 93.33%. While in the treatment without substrate, the cultured worms died entirely on the 3rd day. The best water effect with survival reaching 100% is in the use of seawater and 90% in the use of a mixture of 50% seawater and 50% fresh water.

Some important factors that need to be considered for the optimal growth and survival of marine worms are the rearing substrate, the water used, and the feed provided (Nguyen *et*

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al., 2011; Rasines *et al*., 2023). The use of a substrate with optimal thickness is then a factor that stimulates the growth of marine worms and increases their survival. In their study, Gamis *et al*. (2016) found that substrates with high sand content affected the survival of marine worms, as they had to spend more energy moving through them. The substrate used for marine worm farming is sand and mud, as their natural habitat is usually sandy and muddy estuaries and mangroves (Asnawi *et al*. 2018). Another study also explained that the high catch of marine worms in mangrove areas indicates that mangrove substrates are also suitable for worm growth. Mangrove substrates in the system have ecological value where they can sequester carbon, recover pollutants, prevent abrasion, and prevent storms (Brown *et al*. 2011; Mouneyrac *et al*. 2012). Mangrove substrates can also serve as native habitats for the growth and development of aquatic fauna (Jayachandran *et al*. 2015).

Table 5. Survival Rate of *Nyale*

No	Effect	Type Treatment	Initial Number	Final Number	Survival (%)
1	Substrate	Sand + Seawater	30	28	93.33
		Small rocks + Sea Water	30	28	93.33
		Mixed (sand and small rocks) + Sea Water	30	28	93.33
		Without substrate + Seawater	30	0	0.00
2	Water	Seawater 100%	30	30	100.00
		50 % seawater + 50% freshwater	30	27	90.00
		100% freshwater	30	0	0.00

4.2. Authentic Inquiry Project Practicum Development on *Nyale*

4.2.1. Literature Study

The literature study aims to explore various information related to the right model or method for training and developing students' critical and creative thinking skills. The literature study begins with the analysis and synthesis of recent articles. Based on the results of the literature study, the application of learning in the 21st century must emphasize the training and development of high-level thinking skills. Higher education as a formal institution that prepares graduates to face world progress must provide higher-level skills such as critical and creative thinking skills (Hart *et al*., 2021; Jumrodah *et al*., 2021; Karwowski *et al*., 2020; Young *et al*., 2023).

In the learning process, various methods or models can improve critical and creative thinking skills, but the most important thing is how to develop the learning to be student-centered and able to activate students (Jumrodah *et al*. 2019; Colthorpe *et al*., 2017; Kowalski *et al.,* 2016). In addition to being student-centered, learning must relate what is learned to real environmental problems. Thus, learning becomes meaningful to students (Daikoku *et al*., 2021; Heinimäki *et al*., 2021). Authentic learning will present real-world problems and provide discovery opportunities for students. Authentic inquiry learning developed in the project will give students ample space to think scientifically to find problems and solve problems faced in the real world (Anwar, 2020; Fornsaglio *et al*., 2021; Indorf *et al*., 2019; Li *et al*., 2020; Liang *et al*., 2023).

Polychaeta is a seaworm that in previous studies has many benefits and has been developed in various countries (Chen *et al*., 2020; Kannappan *et al*., 2021; Kim *et al*., 2017; Mandario, 2020; Nesto *et al*., 2018). On Sumba Island, *Nyale* is a collection of various types of marine worms that are included in the Annelida class Polychaeta. *Nyale* is an important icon for the people of Sumba and in a certain month, the community descends en masse to the

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sea to collect it in large quantities. In addition to *Nyale* which is collected during the season when it rises to the surface of the sea, in Sumba there is also known as *Nyale* whose habitat is in the sand and can be taken as bait for fishermen. The removal of *Nyale* from their habitat is feared to affect their survival. This real problem then needs attention. Thus, its sustainability is maintained. In addition, research related to *Nyale* Sumba has not been widely conducted and has not been reported. Thus, there is still a great opportunity to develop meaningful learning by exploring the potential around students.

Based on the above findings, it is necessary to develop an authentic inquiry project practicum program on *Nyale* to improve the critical and creative thinking skills of prospective science teacher students.

4.2.2. Preliminary Study

The implementation of preliminary studies aims to collect various information or data which can then be used as a reference for determining the subject matter of research and program development. The initial stage of the preliminary study was carried out by analyzing the curriculum documents of the Science Education study program at one of the private universities on Sumba Island, Indonesia. The results of the analysis can be described as follows:

(i) Learning in the Science Education study program leads to the application of high-level thinking skills.
(ii) One of the characteristics of the Science Education study program is the integration of learning with local wisdom and potential as well as technological advances by the demands of progress.
(iii) Practicum in science learning is carried out in an integrated manner between theory and practicum.
(iv) One of the scientific courses of the study program that can apply the distinctiveness of the study program is the animal anatomy and physiology course. One of the material topics to be taught is related to Annelida anatomy and physiology.

We then made observations on practicum activities in Basic Biology, Basic Physics, and animal anatomy and physiology courses. Some points found during the observation of practicum implementation include

(i) Practicum is carried out on several topics due to limited laboratory infrastructure.
(ii) The practicum guidebook is like a cooking recipe book that contains the title and objectives of the practicum and contains complete procedures in each stage of the practicum.
(iii) Practicum is still verified, and the preparation of the final practicum report is not well explained. Thus, student practicum reports do not have the same systematics.
(iv) There is no assessment rubric during the practicum process. Thus, the practicum process only takes place to verify some of the theories that have been taught.

The observation results are then reinforced by the findings of the interview results where students feel very helpful in carrying out practicum because they have complete guidelines, but when associated with thinking skills training, this then becomes very ineffective because students only follow instructions without practicing critical and creative thinking skills. The findings of curriculum analysis observations and interviews can provide direction that the course learning process is still focused on mastering concepts. The practicum that takes place aims to verify what has been learned. With this concept, students are not trained with critical and creative thinking skills, and this will have an impact on the low critical and creative thinking skills of prospective science teachers. To prove this, an initial test of critical and

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creative thinking skills was conducted. The results of the critical thinking skills test of Science Education students with Ecosystem material in detail according to indicators (Ennis, 2018). **Table 6** shows that students' critical thinking skills are generally still in the low category. More than 50% of students still get the lowest score of 1 in each indicator of critical thinking skills. The same aspect is shown in the results of the student creative thinking skills test shown in **Table 7**. Most students still get the lowest score of 1 and some even get a score of 0 which means no answer or even a wrong answer.

Table 6. Student critical thinking skills

Aspects	Average	Score	Student Answer (%)
Elementary clarification	1.48	0	0.00
		1	60.00
		2	30.00
		3	10.00
Basic support	1.42	0	0.00
		1	63.33
		2	33.33
		3	3.33
Inference	1.29	0	3.33
		1	80.00
		2	13.33
		3	3.33
Advance Clarification	1.87	0	6.67
		1	10.00
		2	83.33
		3	0.00
Strategy and Tactics	1.19	0	10.00
		1	76.67
		2	6.67
		3	6.67

Table 7. Student creative thinking skills test

Aspects	Average	Score	Student Answer (%)
Fluency	1.74	0	6.67
		1	26.67
		2	66.67
		3	0
		4	0
Flexibility	1.64	0	6.67
		1	43.33
		2	50
		3	0
		4	0
Originality	1.74	0	20
		1	33.33
		2	46.67
		3	0
		4	0
Evaluation	1.03	0	0
		1	100
		2	0
		3	0
		4	0

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4.2.3. Development of Authentic Inquiry Project Practicum on *Nyale*

In the development stage, the practicum guidebook is developed by referring to the program design that has been designed. The authentic inquiry project practicum guidebook on *Nyale* contains:

(i) Practicum Implementation Plan which contains learning steps, lecturer activities, student activities, methods used, critical and creative thinking skills that are trained in the practicum, time allocation, and sources/media/tools. The method used in practicum is an authentic inquiry project by combining a level of inquiry model type real word application and hypothetical inquiry. Practicum implementation is carried out with the syntax: (a) formulating questions, (b) planning projects, (c) carrying out projects, (d) collecting data, (e) drawing conclusions, and (f) communicating results.

(ii) Student worksheets serve to direct students regarding the implementation of what is done during the practicum. Thus, there is no bias or error. Student Worksheets are also designed. Thus, students can communicate and collaborate and form students' critical and creative thinking skills.

(iii) The assessment sheet contains (a) a rubric for assessing the ability to design projects, (b) a rubric for assessing the ability to carry out and report results, (c) a rubric for product assessment, and (d) a test instrument for students' critical and creative thinking skills. An example of the completeness of the Guidebook developed is shown in **Table 8**.

Table 8. The guidebook of authentic inquiry project practicum on *Nyale*

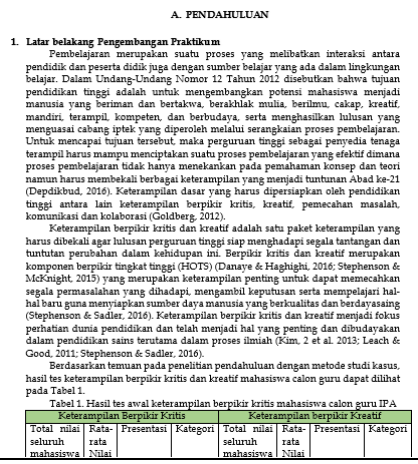
No	Parts	Figure	Description
1	Cover		The cover contains cover, foreword, and table of contents
2	Introduction	 A. PENDAHULUAN 1. Latar belakang Pengembangan Praktikum Pembelajaran merupakan suatu proses yang melibatkan interaksi antara pendidik dan peserta didik juga dengan sumber belajar yang ada dalam lingkungan belajar. Dalam Undang-Undang Nomor 12 Tahun 2012 disebutkan bahwa tujuan pendidikan tinggi adalah untuk mengembangkan potensi mahasiswa menjadi manusia yang beriman dan bertakwa, berakhlak mulia, berilmu, cakap, kreatif, mandiri, terampil, kompeten, dan berbudaya, serta menghasilkan lulusan yang menguasai cabang iptek yang diperoleh melalui serangkaian proses pembelajaran. Untuk mencapai tujuan tersebut, maka perguruan tinggi sebagai penyedia tenaga terampil harus mampu menciptakan suatu proses pembelajaran yang efektif dimana proses pembelajaran tidak hanya menekankan pada pemahaman konsep dan teori namun harus membekali berbagai keterampilan yang menjadi tuntunan Abad ke-21 (Depdikbud, 2016). Keterampilan dasar yang harus dipersiapkan oleh pendidikan tinggi antara lain keterampilan berpikir kritis, kreatif, pemecahan masalah, komunikasi dan kolaborasi (Goldberg, 2012). Keterampilan berpikir kritis dan kreatif adalah satu paket keterampilan yang harus dibekali agar lulusan perguruan tinggi siap menghadapi segala tantangan dan tuntutan perubahan dalam kehidupan ini. Berpikir kritis dan kreatif merupakan komponen berpikir tingkat tinggi (HOTS) (Danaye & Haghighi, 2016; Stephenson & McKnight, 2015) yang merupakan keterampilan penting untuk dapat memecahkan segala permasalahan yang dihadapi, mengambil keputusan serta mempelajari hal-hal baru guna menyiapkan sumber daya manusia yang berkualitas dan berdayasaing (Stephenson & Sadler, 2016). Keterampilan berpikir kritis dan kreatif menjadi fokus perhatian dunia pendidikan dan telah menjadi hal yang penting dan dibudayakan dalam pendidikan sains terutama dalam proses ilmiah (Kim, 2 et al. 2013; Leach & Good, 2011; Stephenson & Sadler, 2016). Berdasarkan temuan pada penelitian pendahuluan dengan metode studi kasus, hasil tes keterampilan berpikir kritis dan kreatif mahasiswa calon guru dapat dilihat pada Tabel 1. Tabel 1. Hasil tes awal keterampilan berpikir kritis mahasiswa calon guru IPA Keterampilan Berpikir Kritis | Keterampilan berpikir Kreatif Total nilai seluruh mahasiswa | Rata-rata Nilai | Presentasi | Kategori | Total nilai seluruh mahasiswa | Rata-rata Nilai | Presentasi | Kategori	The introduction contains the background to the development of the practicum guidebook and the aims of the practicum

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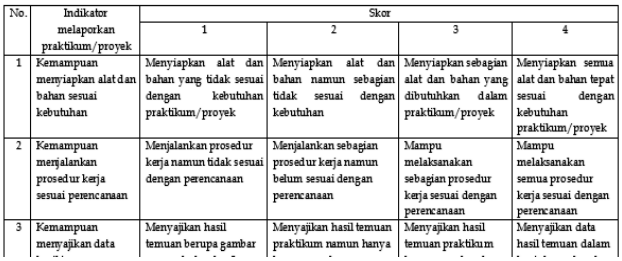
Table 8 (Continue). The guidebook of authentic inquiry project practicum on *Nyale.*

No	Parts	Figure	Description
3	Authentic Inquiry Project Practicum Guide About Nyale	RENCANA PELAKSANAAN PRAKTIKUM KE-6 Mata Kuliah : Anatomi dan Fisiologi Hewan Kemampuan Akhir yang direncanakan: 1. Berkontribusi dalam peningkatan mutu kehidupan bermasyarakat dengan melihat masalah dan memberikan solusi secara kritis dan kreatif 2. Mampu bekerjasama dalam kelompok dalam mengerjakan perencanaan sampai pada tahapan penyelesaian. 3. Memiliki kepekaan dalam melihat tradisi yang ada dilingkungannya dan mampu mengidentifikasi masalah pada tradisi Timba Nyale 4. Mensintesis informasi dan data untuk keperluan identifikasi *nyale* 5. Mensintesis informasi dan data untuk merencanakan dan merancang pembudidayaan *Nyale* 6. Kritis dan kreatif dalam praktikum identifikasi dan budidaya Annelida salah satunya *Nyale* berbasis *Authentic inquiry project* Alokasi Waktu : 160 Menit Topik Praktikum : **Perencanaan Praktikum Pengambilan Sampel *Nyale*, identifikasi *Nyale* dan Budidaya *Nyale*** Langkah Kegiatan Praktikum :  LEMBAR KERJA MAHASISWA 1 **TOPIK: PERENCANAAN PRAKTIKUM LAPANGAN, IDENTIFIKASI NYALE DAN BUDIDAYA NYALE** Petunjuk: 1. Bacalah dengan teliti suruhan dalam mengerjakan lembar kerja perencanaan praktikum Identifikasi dan Budidaya *Nyale*. 2. Bacalah berbagai sumber dan cobalah menjawab setiap pertanyaan dalam lembar kerja ini dan merancang perencanaan praktikum yang dapat menjawab tujuan pembelajaran. Cantumkan sumber yang kalian gunakan! 3. Kerjakan secara bersama dalam kelompok dan konsultasikan hasil diskusi dengan Dosen untuk mendapatkan arahan dan masukan! 4. Lembar Kerja ini bersifat wajib dan akan diperiksa sebelum kelompok akan melakukan praktikum lanjutan! Tujuan Pembelajaran: 1. Melalui *inquiry textbook application*, mahasiswa dapat mengidentifikasi masalah pada tradisi timba *Nyale* 2. Melalui *inquiry textbook application*, mahasiswa dapat mensintesis informasi dari berbagai sumber kemudian merencanakan praktikum pengambilan sampel, Budidaya dan Pengamatan struktur tubuh serta identifikasi *Nyale*. 3. Melalui *inquiry textbook application*, mahasiswa memiliki kepekaan social dan	The practicum guide contains practicum implementation plans and student worksheets
4	Evaluation	2. Rubrik Penilaian Kemampuan Melaksanakan dan Melaporkan Hasil Praktikum  Pre-test **Nama** : **NIM** : **Semester/Kelas** : **Mata Kuliah** : **Anatomi dan Fisiologi Hewan** **Dosen Pengampuh** : **Geterudis Kerans, S.Pd., M.Sc.** ⇨ Petunjuk 1. Isilah identitas anda terlebih dahulu. 2. Bacalah soal dengan baik sebelum mengerjakannya 3. Setiap soal bersifat wajib 4. Soal bersifat closebook ⇨ Soal 1. **Jelaskan secara singkat pemahaman anda tentang *Nyale*!** …… …… …… …… ……	The assessment contains assessment rubrics and assessment instruments for practical activities and test questions for students' critical and creative thinking skills.

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4.2.4. Testing and Evaluation

After going through expert validation and revision based on the results of expert validation of the program design and practicum guidebook, the next stage was limited testing. The trial was conducted with various topics of activities, including (i) Program planning; (ii) Habitat observation and sampling of *Nyale*; (iii) *Nyale* cultivation, and (iv) *Nyale* identification. The test results in the form of student test scores were then tested for validity and reliability. The results of the analysis of critical and creative thinking skills test items using Excel and SPSS 23 are shown in **Table 9**. Based on the results, the results of the analysis show that of the 10 numbers of questions tested, there is one invalid question that still meets the other 3 criteria. Thus, it needs to be revised and then can be used. The questions developed are related to measuring students' critical and creative thinking skills after undergoing an authentic inquiry project practicum on *Nyale*. In the implementation of the trial using the guidebook developed, several revision notes were obtained that needed to be corrected for improvements related to student worksheets.

The massive development and advancement of science and technology encourage higher education institutions to prepare their graduates as individuals who can compete globally (Bellaera *et al*., 202). One of the important objectives of higher education is to equip students with various 21st-century thinking skills such as critical and creative thinking skills (Gellin, 2003; Jumrodah *et al*., 2021; Levin-Goldberg, 2012). Critical and creative thinking skills relate to an individual's ability to identify, analyze, synthesize, and evaluate information to be used in decision-making. Critical thinking teaches individuals to be able to be selective and reflective in managing information to take the right action (Jumrodah *et al*., 2019; Stephenson & Sadler-Mcknight, 2016). Creative thinking skills are one of the key factors in dealing with various problems in the Industrial Revolution 4.0 era (Hecklau *et al*., 2016) and have a positive impact on personal, social, and environmental development (Kutlu & Gokdere, 2015; Putri & Witarsa, 2023; Rif'at *et al*., 2021).

Table 9. Validity and Reliability Result using Excel and SPSS 23.

No.	Validity		Reliability (Cronbach alpha)	Discriminant		Difficulty		Decision
	r	Description		DP	Description	TK	Description	
1	0.64	Valid	0.818 (Extremely High)	0.46	Good	0.65	Medium	Used
2	0.43	Valid		0.31	Medium	0.50	Medium	Used
3	0.36	Invalid		0.46	Good	0.70	Medium	Revised
4	0.71	Valid		0.69	Very Good	0.50	Medium	Used
5	0.73	Valid		0.15	Poor	0.46	Medium	Used
6	0.61	Valid		0.15	Poor	0.54	Medium	Used
7	0.53	Valid		0.15	Poor	0.50	Medium	Used
8	0.76	Valid		0.62	Very Good	0.50	Medium	Used
9	0.59	Valid		0.46	Good	0.50	Medium	Used
10	0.71	Valid		0.62	Very Good	0.67	Medium	Used

In an authentic learning environment, students exercise cognitive, physical, and interpersonal skills from the project. Thus, they can connect real-world problems with concepts together (Anstey, 2017). Inquiry learning provides space for students to discover and improve content understanding, facilitates meaningful and in-depth learning, improves performance, strengthens student satisfaction in the learning process, and encourages active involvement in learning (Apedaile, 2020; Huda, 2017; Yuan *et al*., 2020). Practicum based on authentic inquiry projects can provide space for students to develop critical and creative

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thinking skills through projects that raise real problems. Finally, this study can support current issues in the SDGs.

5. CONCLUSION

The types of substrates and water are important factors for cultivating *Nyale*. The substrate such as sand and coral can be used in cultivation. Seawater is the best type of water that can be used in cultivation. Water quality also needs to be considered in the cultivation. This study also demonstrates the cultivation of *Nyale* for supporting the teaching and learning of prospective teachers, which can improve critical and creative thinking skills. This study also presents real-life problems, especially supporting current issues in the SDGs.

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7. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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