Promoting Students' Anticipatory Competency through the Rainwater Harvesting System Learning Project

N. A. Lestari[1*], **A. Widodo[2]**, **E. Eliyawati [3]**

[1,2,3] *Science Education, Faculty of Mathematics and Sciences Education, Universitas Pendidikan Indonesia*
Corresponding Author. Email: nimasayulestari@upi.edu

Abstract

In response to the pressing global challenges of climate change and water scarcity, the education sector seeks innovative approaches to nurture students' anticipatory competency. This study aims to investigate the improvement of students' anticipatory competency through rainwater harvesting system learning project. The method used in this research was Quasi-Experimental with Non-Equivalent Control Group Design research design. The sample used was class VII students consisting of a control class and an experimental class of 20 students each. Data were collected both before and after learning to assess students' anticipatory competence. The results showed that there was the significant different on Anticipatory competency in the experimental class. This means that rainwater harvesting system learning project effect on students' anticipatory competency The study implies positive impacts of utilizing the rainwater harvesting system learning project on students' anticipatory abilities to shape a future generation ready to tackle clean water and proper sanitation issues.

INTRODUCTION

Indonesia's tropical climate, marked by heavy equatorial rainfall and occasional droughts, holds vital implications for education, health, society, and the economy. Water scarcity intensifies due to climate change, affecting diverse sectors. Education plays a crucial role in addressing climate change. Moreover education holds a pivotal position in achieving the Sustainable Development Goals (SDGs) (Eliyawati et al., 2023). The United Nations emphasizes Education for Sustainable Development (ESD) to cultivate awareness and readiness for the climate crisis. ESD is a central global and national educational goal, focusing on sustainability. Anticipatory competency is an integral ESD component, enabling adaptability, creativity, and effective decision-making. This skill empowers students to navigate uncertainties and contribute positively to society and the environment. Indonesia's vulnerability to disasters underscores the need for

disaster anticipation education, which remains underdeveloped in the education system

In Indonesia dealing with disasters, awareness of disaster anticipation is still low, and there is still a lack of school involvement in introducing disaster anticipation education (Seddighi et al., 2022). Disaster anticipation activities aim to increase community preparedness and reduce disaster risk for the long term, reduce the number of victims, and implement as much as possible to minimize the impact. Anticipatory competency in junior high schools remains low and there is not much research on students' anticipation competency (Hasanah, 2021). And the mindset of Indonesian people's anticipatory competency to avoid the impact of climate change cannot classify as good (Brechin & Bhandari, 2011)

Applying stem-based learning with the rainwater harvesting project can help students improve their anticipatory competency in natural disasters due to the severity of climate change in

Indonesia. In STEM-based learning, during the design phase, students are required to anticipate the behavior of the technology they create and its impact on the environment and society (Zizka & Varga, 2020). STEM learning significantly improves students' problem-solving abilities (Kartini et al., 2021). Problem-solving abilities are crucially related to anticipatory competency, which involves anticipating potential future scenarios, consequences, and challenges, enabling individuals to identify and address future issues effectively. By focusing on projects and challenges relevant to real-life contexts, students learn to anticipate the consequences of their actions and design more sustainable and responsible solutions (Aránguiz et al., 2020; Sobari et al., 2022).

The problem identification stage in STEM learning, specifically focused on water scarcity due to climate change in Bandung, is vital for boosting students' comprehension and ability to assess various solutions. It aids in integrating environmental, social, and economic aspects into decision-making for development. In the testing phase, students assess the effectiveness of their designs, identify issues, and observe outcomes, fostering an understanding of the link between design actions and results, along with opportunities for enhancements. STEM learning cultivates students' capacity to enhance their abilities in facing risks and changes. by emphasizing problem identification, exploration, and experimentation (Astuti et al., 2021; Prawvichien et al., 2018)

RESEARCH METHOD

The method used in this research is the Quasi Experiment. The design was a pretest-posttest non-equivalent control group design (Creswell, 2014). In this study, two groups were observed: the experimental group through the rain harvesting system project in terms of water cycle and the control group using conventional methods through the usual teaching methods employed by the teacher for the water cycle topic, and both groups were taught by the same teacher. This design shows in the table 1

Table 1. Research Design of Two Group Pre-test and Post-test

Class	Pre-test	Experiment	Post-test
Experiment	O_1	X	O_2
Control	O_1	-	O_2

The population in this study was 7th grade students from a private junior high school in Bandung, using the Merdeka Curriculum. Two classes, experimental and control, each with 20 students, were selected as samples. The sampling method employed probability sampling to ensure similarity in baseline knowledge and no prior exposure to the water cycle topic.

The students' anticipatory competence in this study will be observed in a questionnaire developed from five indicators initiated by UNESCO (2017). The five indicators are the ability to (1) understand and evaluate various possibilities; (2) determine the vision for the future; (3) apply the precautionary principle; (4) assess the consequences of an action; and (5) face risk and change. There are a total of 20 questions, each comprising a questionnaire item paired with a 4-point Likert scale. The questionnaire items were directly created by the researcher and evaluated by two lectures. Following this, the instrument's feasibility was examined through validation and reliability test involving 35 junior high school students in Bandung. The analysis was conducted employing the SPSS version 25 software.

RESULT AND DISCUSSION

Anticipatory competency is encompassing their ability to predict and forecast, factors influencing the study outcomes, and the relationship between the applied treatments and indicators of anticipatory competency. Initial pretest scores for both experimental and control groups indicated a limited agreement level (scale range of 2) with statements about climate change concepts, perceptions, and actions. After the rainwater harvesting project, the experimental group's agreement increased by one level, showcasing an encouraging positive trend in anticipatory competence enhancement. In Table 2 reveals the results of the hypothesis test following the intervention, it was found that there was a significant difference emerged in students' scores. This underscores the project's potential to elevate students' anticipatory competence concerning future climate change effects on water availability. The analysis aligns with previous research highlighting the importance of involving students in hands-on experiences, such as designing prototype in STEM learning, which positively influences their community; such experiences provide valuable opportunities for students to develop action-oriented strategies that showcase their anticipatory competencies (Prawvichien et al., 2018; Rios et al., 2018)

Table 2. Anticipatory Competency Statistical Test Results

Data type		Pretest		Posttest	
Class		Experiment	Control	Experiment	Control
N		20	20	20	20
Mean		2.63 (Disagree)	2.65 (Disagree)	3.36 (Agree)	2.99 (Disagree)
Standard deviation		0.207	0.210	0.197	0.270
Normality test (*shapiro wilk*)	Sig.	0.742	0.004	0.269	0.231
	Interpretation	Normal distribution	Non-normal distributions	Normal distribution	Normal distribution
Homogenity tes (*levene test*)	Sig.	0.734		0.154	
	Interpretation	Homogen		Homogen	

Understand and evaluate various possibilities

The first indicator of the dependent variable of anticipatory competency is the ability to understand and evaluate various possibilities. This relates to students' ability to comprehend and assess the different possibilities that may occur regarding a potential, impending, or predicted event. Predicting as many probabilities as possible related to future issues and critically examining those scenarios to identify which behaviors need to be modified (Scherak & Rieckmann, 2020). Students not only need to recognize that climate change phenomena are indeed happening but also need to be aware that future projections have the potential to become reality, serving as a basis for action based on emerging ideas (Forsler, 2017).

The results of the hypothesis testing demonstrate a significant difference in posttest scores between the experimental and control groups. These findings strongly suggest that the implementation of the Rainwater Harvesting System Project in the experimental class has a noteworthy and statistically significant positive impact on enhancing the ability to understand and evaluate various possibilities.
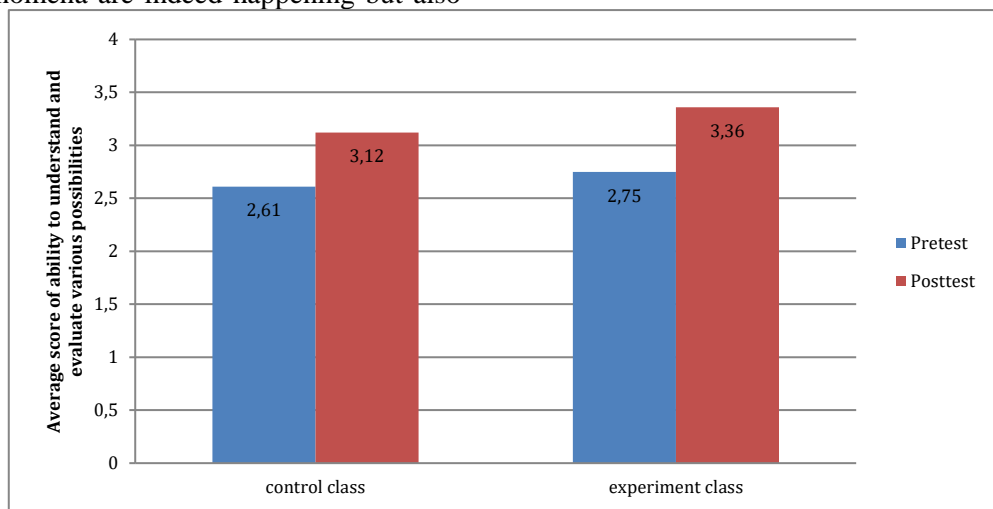
Figure 1. The difference in the average score of the ability to Understand and evaluate various possibilities between the experimental and control class.

Based on the results presented in Figure 1, the average pretest and posttest scores in both the experimental and control classes indicate a similar numerical range. And they both experienced a change in their ability to understand and evaluate various possibilities from the response "disagree" to "agree". Nevertheless, the average posttest score in the experimental class showed a higher increase compared to the control class. The improvement in average posttest scores observed in the experimental class can be attributed to the various stages involved in the Rainwater Harvesting

System Project as part of the learning process. One crucial stage is the identification of the problem, where students are presented with a real-life case study highlighting the water scarcity issues in Bandung due to climate change. During identification of the problem stage, students are actively engaged in understanding the problem, analyzing its causes, and recognizing the implications of limited water availability on the local community by answering several questions on Figure 2.
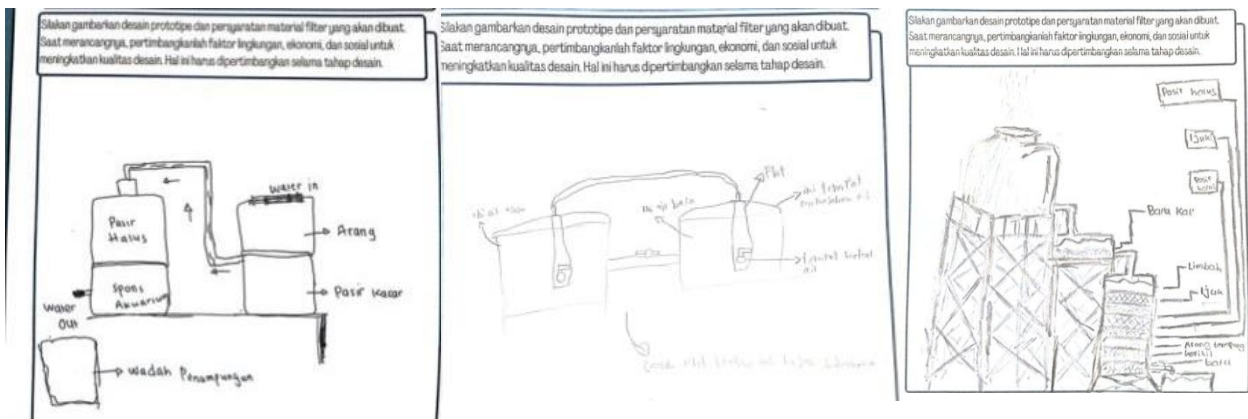
Figure 2 Student worksheet section designing prototypes

By immersing themselves in this realistic scenario, students develop a deeper understanding of the challenges posed by climate change and the urgent need for sustainable water management solutions. The identification of the problem serves as a critical starting point, as it not only raises awareness but also stimulates critical thinking and problem-solving skills among students (Feby Octafianellis et al., 2021; Kardoyo et al., 2020; Puspita & Aloysius, 2019). By grappling with the complexities of the situation, students are encouraged to explore different possibilities and evaluate potential solutions (Mentzer et al., 2015).
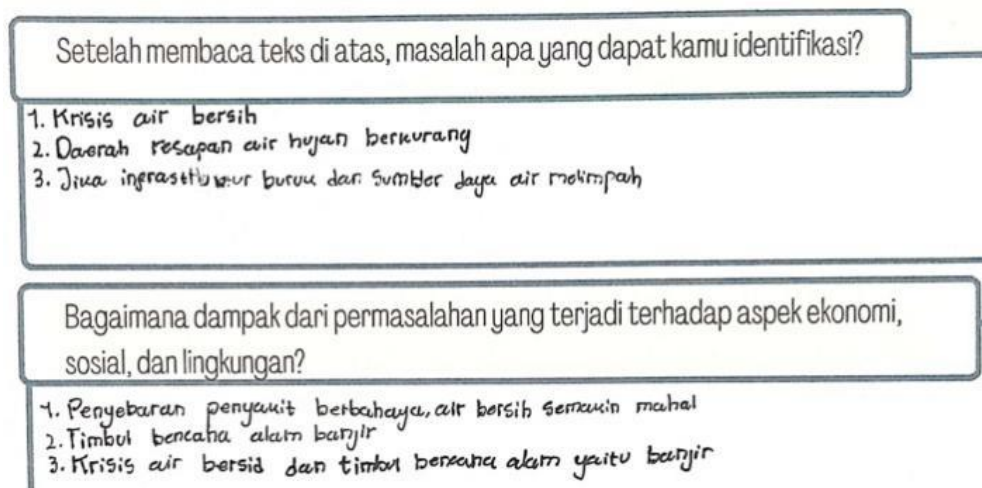

Figure 2 Responses from Group 2 on the student worksheet: identification problems

Based on the analysis of Group 2's responses in Figure 3, it is evident that students are aware of the potential for various future disasters resulting from current human activities, such as rapid development without considering water infiltration areas. This demonstrates students' ability to predict as many potential future issues as possible. The predictions made by the students refer to the connection between development that neglects water infiltration areas and the potential disasters that may arise across various aspects, including environmental, social, and economic factors. In terms of the environment, students are aware that such development can lead to floods, landslides, groundwater quality depletion, drought, and ecosystem degradation. Furthermore, students also consider the social aspects that may be affected, such as the spread of diseases resulting from environmental and water disruptions. Additionally, they acknowledge that development disregarding water infiltration areas also has economic repercussions, particularly in terms of increased prices of clean water due to declining availability of quality water resources.

These findings indicate that students are capable of identifying potential consequences that may arise in the future due to the imbalance between rapid development and the preservation of water infiltration areas. The stage of problem identification, specifically focusing on the water scarcity issue in Bandung caused by climate change, plays a crucial role in enhancing students' understanding and their capacity to evaluate different possibilities in addressing this challenge and incorporating environmental, social, and economic factors into decision-making processes related to development.

Determine the vision for the future

The second indicator of anticipatory competency is the ability to determine a vision for the future. It is defined as the ability to foster dreams and future thinking through imaginative and wise imagination, envisioning diverse processes that enable and generate multiple scenarios as a result (Uwasu et al., 2020). The ability to determine a vision for the future is more focused on choosing desired futures to avoid the detrimental impacts of climate change (Paprocki & Huq, 2018; Rieckmann, 2012).

The results of the hypothesis test indicate a significant difference in the posttest scores between the experimental and control classes. These findings suggest that the implementation of the Rainwater Harvesting System Project in the experimental class has enhanced the indicator of anticipatory competence, specifically the ability to determine a vision for the future. Furthermore, there was a notable increase of 0.83 points in the average scores of the experimental class.
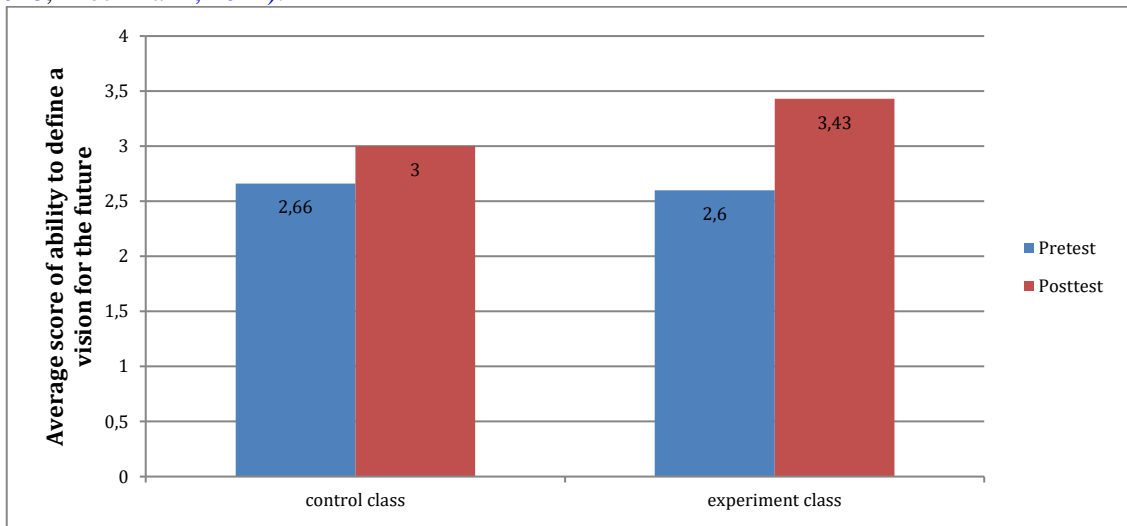
Figure 3. the difference in the average score of the ability to determine the vision for the future between the experimental and control class

Based on Figure 4, there is a significant difference in the average posttest scores between the control and experimental classes. However, both the control and experimental classes experienced an improvement, starting from a range disagree, and transitioning to a range "agree," after the implementation of the learning interventions.

Although the experimental class showed a higher increase more than control class. It influenced by several factors, one of which is the identification problem stage in Activity 2 of the student worksheet, which helps enhance the students' ability to determine a vision for the future.

Table 3. Students' response on student worksheet activity 2: identification problems

Questions	Answer		
	Group 1	Group 2	Group 3
According to your investigation, what problems did you find with rainwater?	The water is acidic and contains bits of dirt so it is not good for living creatures to consume, but it can be used daily	It is acidic because its pH is 6	Rainwater is not clean so the sea is not clean, the pH is 6
What are the indicators of water that is safe to use for daily needs?	Colorless, odorless, clear, pH 6.5-8.5	pH 7, clear, no odor, clear color, does not itch	Odorless, clear color, tasteless
Based on the analysis of the suitability of rainwater that you have carried out. Is it safe to use rainwater for daily needs? Why?	Safe for watering plants, washing the yard, but not for consumption, there is still a little dirt	It's safe if it's clear and odorless	Not safe for consumption and not used for cooking because the pH is acidic, not neutral

After students have engaged in a series of activities, such as conducting chemical and physical tests on rainwater samples, they are required to answer several questions on a student worksheet, as shown in Table 3, which leads to the exploration of the potential use of rainwater as a source of water for daily needs. The students analyze the feasibility of using rainwater, taking into consideration factors such as water quality and safety in its usage, by gathering relevant information and determining whether rainwater can be safely utilized for daily needs.

In order to establish a future vision, strong justifications are necessary to create a compelling inclination towards its achievement (Ghari, 2018). The questions in Table 3 direct students to form a conclusion regarding the reasons why they should develop a tool for rainwater management. These questions also stimulate critical thinking and further research by students, which can contribute to a better understanding of the potential use of rainwater in the context of sustainability and future water needs. Critical thinking skills are essential in formulating an informed and directed vision for the future (Hunter et al., 2018; Knap-Stefaniuk & Ambrozová, 2021)

Engaging in well-planned activities strengthens the ability to determine a future vision (Kabeyi, 2019). In the phase of constructing the prototype, students are guided to identify the necessary tools, materials, and procedures for creating a prototype as an effort to establish a robust plan for the project. By actively participating in well-planned activity planning and contributing to the development of prototypes, students further enhance their organizational and project management skills. They learn how to effectively allocate resources, establish timelines, and coordinate tasks to ensure the smooth execution of the project. These skills are crucial in transforming a vision for the future into a well-structured plan that can be successfully implemented.

Apply the precautionary principle

The third indicator of anticipatory competency is the ability to apply the precautionary principle. Applying the precautionary principle involves making decisions based on scientific facts regarding potential, impending, or predicted problems. It also entails the capacity to adhere to and implement views related to the obligation to seek and develop comprehensive plans to avoid environmental damage by restraining activities that could potentially harm the environment (Martuzzi, 2007). The essence of the precautionary principle focuses on human and environmental safety within the occupied space and is a common subject in fields ranging from law to politics due to its relevance and involvement of policymakers (Hansson, 2020)

The results of the hypothesis testing indicate a significant difference in the posttest scores between the experimental and control classes. These findings suggest that the implementation of the Rainwater Harvesting System Project in the experimental class has a significant positive impact on improving students' ability to apply the principle of caution. Furthermore, there was a noteworthy increase of 0.45 points in the average scores of the experimental class.
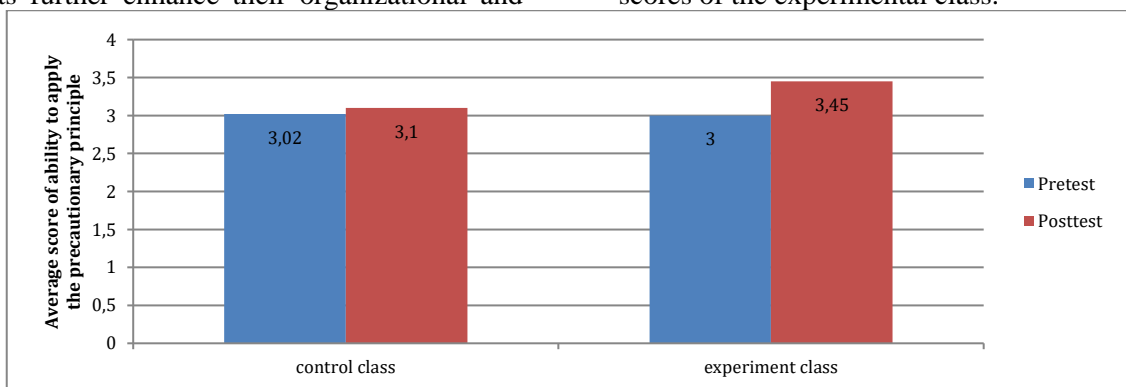
Figure 4 the difference in the average score of the ability to Apply the precautionary principle between the experimental and control class

Although in Figure 5, the average pretest and posttest scores for both groups of classes have the same range of 3, indicating a level of agreement with the meaning "agree," it implies that before the implementation of the learning, students already had a positive inclination towards the ability to apply the precautionary principle. However, there was an increase in the average posttest scores in the experimental class. This improvement can be attributed to the stages involved in the Rainwater Harvesting System Project as part of the learning activities.
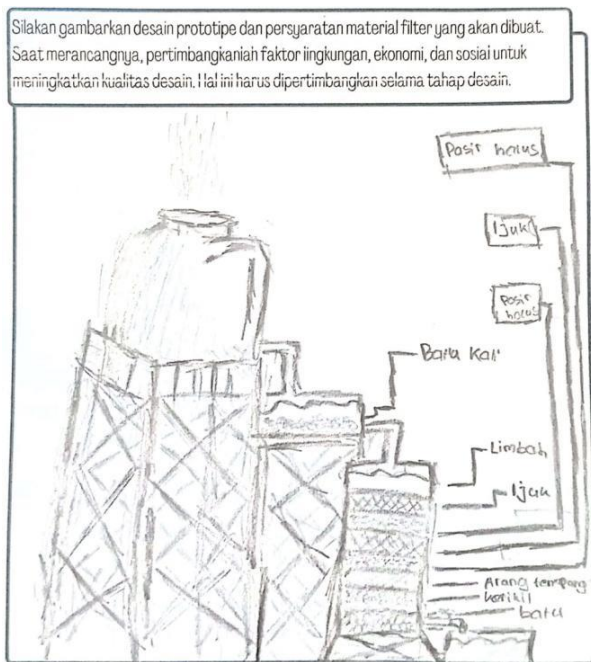
Figure 5. Group 3 prototype designs

In the design phase of the rainwater harvesting system project, students are faced with the demand to consider environmental, social, and economic factors in a holistic manner. As the design process unfolds, the teacher asks for the reasons behind Group 3's choices in designing the rainwater harvesting system in Figure 6 The teacher aims to deeply understand why the students decided to create a rainwater harvesting design with a specific concept, hoping to help them see a broader perspective, particularly in terms of sustainability aspects.

> "The materials are found around the house, for stones, sand you can use what's in your yard too, for tools you can use what you have at home such as barrels and old pipes that you don't use. When the tool is finished, it can be placed in the yard, the fence can be attached to hanging plants " (group 3)

Based on the teacher's interview findings during the students' design process, asking why they chose those materials and tools, it shows that the students prioritize material selection criteria that include affordability, easy availability of materials, ease of fabrication, and minimal energy usage. They also consider the use of recycled materials, such as the use of old pipes in the prototype installation, as an effort to achieve environmental sustainability. Interestingly, Group 3 also considered the art value of the tool by utilizing it as a hanging pot for plants.

In the process of designing a rainwater harvesting prototype, Group 3 emphasizes the principle that the designed tool should be easily

produced and require minimal energy, with the goal of being adopted by many individuals. In terms of economic aspects of material selection, the students strive to keep the production costs affordable, ensuring that the prototype they design does not become expensive. However, they are also aware of the importance of maintaining water conservation goals and future expenditure savings.
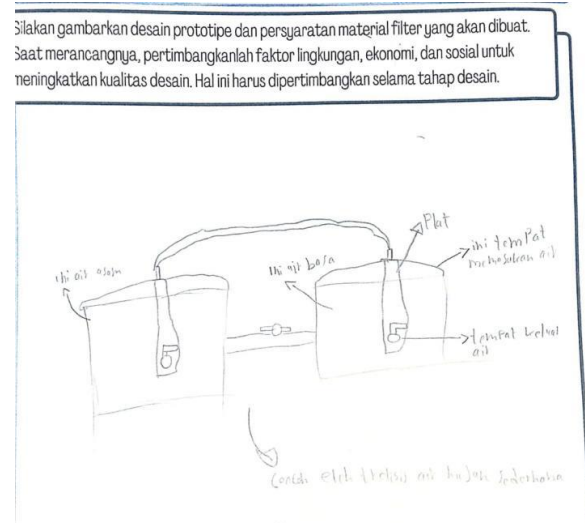

**Figure 6.** Group 2 prototype designs

Group 3 exhibits a design that lacks innovativeness and fails to effectively resolve the issue of rainwater, particularly the problem of rainwater acidity. Consequently, Group 2 in Figure 3.7 is regarded as employing a more effective and innovative approach in addressing rainwater-related challenges, specifically in tackling the issue of rainwater acidity by separating acidic and basic components of water using electrolyte plates based on the principle of electrolysis. Although the implementation of Group 2's design was ultimately unfeasible, their problem-solving capabilities outshine those of other groups, as evidenced by their design showcased in Figure 7. These outcomes highlight their prudent application of design principles by considering environmental, social, and economic factors to ensure sustainability and preempt future predicaments.

Assess the consequences of an action

The fourth indicator of anticipatory competency is the ability to assess the consequences of an action. This refers to students' ability to evaluate the consequences of an action taken regarding potential, impending, or predicted events. The ability to assess the consequences of an action is closely tied to an individual's viewpoint on human activities as a contributing factor to climate change, and it is considered a powerful predictor of how someone perceives risks and takes part in mitigation efforts (Armah et al.,

2017; Hoogendoorn et al., 2020; Xie et al., 2019). Assessing the consequences of an action can also be done through forward thinking by considering both short-term and long-term consequences that may occur when making a decision (Wiek et al., 2011). Moreover, investigating the underlying causes of climate change is a key focus within the realm of mitigation research and serves as a sustainable education (Creutzig et al., 2018; Mi et al., 2019).

The results of the hypothesis test indicate a significant difference in the posttest scores between the experimental and control classes. These findings suggest that the implementation of the Rainwater Harvesting System Project in the experimental class has enhanced the indicator of anticipatory competence, specifically the ability to evaluate the consequences of an action. Furthermore, there was a notable increase of 0.30 points in the average scores of the experimental class.
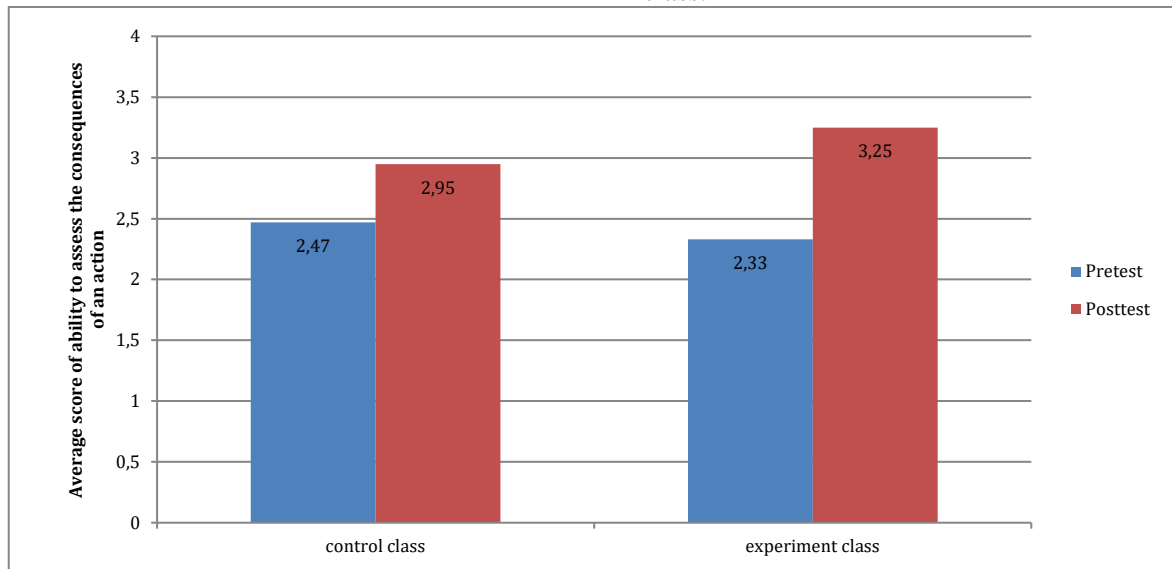
Figure 7. The Difference in the Average Score of the Ability to Assess the Consequences of an Action between the Experimental and Control Class.

Based on Figure 8, there is a significant difference in the average scores of posttest between the control and experimental classes. The control class, despite experiencing an increase in the average score, did not demonstrate any significant change in their pretest and posttest scores regarding their ability to confront risk and adapt to change. Conversely the experimental class showed an increase in the average scores and witnessed a shift in student responses from the "disagree" to the "agree" category. These findings suggest that the utilization of the Rainwater Harvesting System project as a learning approach can enhance students anticipatory competency specifically ability to consequences of an action.

The improvement in average posttest scores observed in the experimental class can be attributed Rainwater Harvesting System Project as part of the learning process. In STEM learning, when students engage in activities involving testing and redesigning prototypes, it supports their ability to comprehend the consequences of actions.
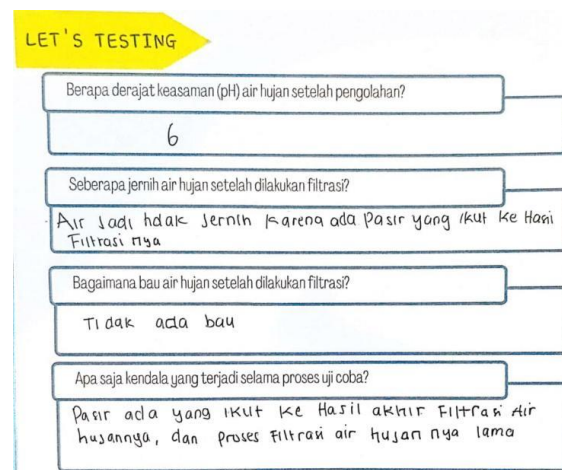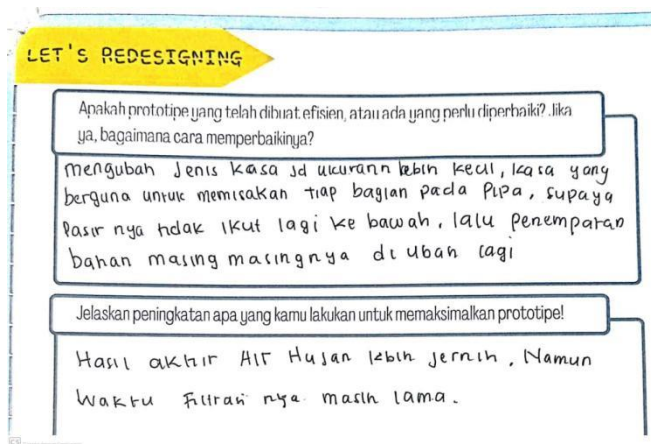

Figure 8 Response of group 1 on the student worksheet: testing stage

In the testing phase, students are able to assess the success or failure of their designs, identify problems, and observe the impact of the decisions they made. Group 1 conducts tests on the tool they created and records their findings on the student worksheet in Figure 9. Through this process, they learn how actions taken in prototype design can have different consequences and how they can make improvements. In Group 1's case, they encountered obstacles where the sand used ended up being part of the final result of rainwater

filtration, and the rainwater management process took a considerable amount of time.

Figure 9 Response of group 1 on the student worksheet: re-design stage

Subsequently, in the prototype redesign phase, students are given the opportunity to refine their designs based on the results of previous testing. In this process, they must consider the consequences of the changes they make and think of better solutions to address the existing issues. Group 1 in Figure 10 made changes to the sequence of materials and adjusted the size of the mesh barriers in each pipe as an effort to tackle the problem of sand getting into the final result of rainwater filtration.

Thus, through testing and redesigning the prototype, students actively engage in understanding and experiencing the consequences of their actions. This helps them enhance their understanding of the relationship between actions

taken in design and their impacts, as well as sharpen their ability to consider consequences in decision-making.

Face risk and change

Coping with risks and changes involves dealing with the risks and changes that may occur regarding potential, impending, or predicted events. It is also a derivative of the concept of uncertainty, reflected by the ability of an individual or community to assess the costs required to cope with the losses caused by climate change and transition to a low-carbon economy in the long term (Gillingham et al., 2018; Mehta et al., 2019). This ability also falls under the concept of inertia, which can be examined by evaluating an individual's readiness to make decisions based on a thorough analysis of the potential losses and gains associated with each available option, even though it is known that no option is capable of completely avoiding the impacts of climate change. It is important to understand that every choice carries risks (Wang et al., 2023).

The results of the hypothesis test indicate a significant difference in the posttest scores between the experimental and control classes. These findings suggest that the implementation of the Rainwater Harvesting System Project in the experimental class has enhanced the indicator of anticipatory competence, specifically the ability to face risks and changes. Furthermore, there was a notable increase of 0.82 points in the average scores of the experimental class.
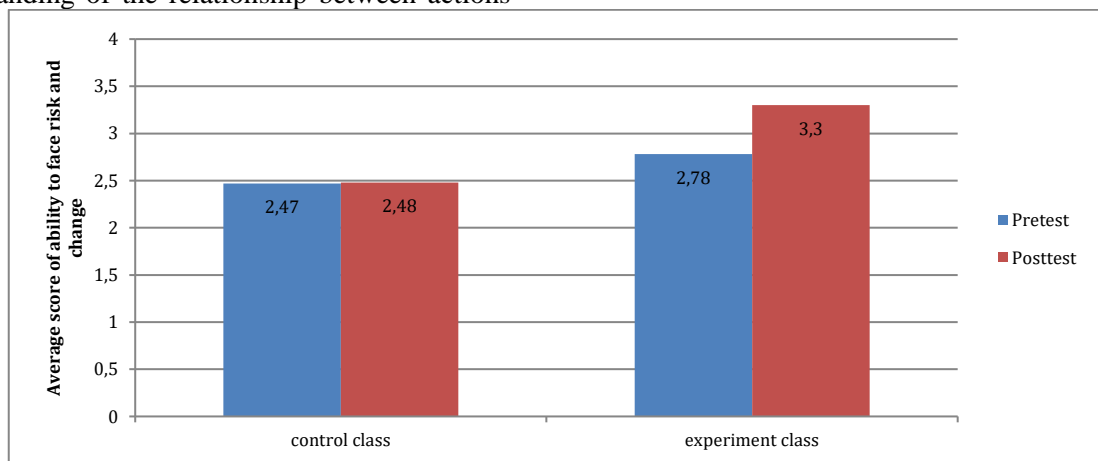
Figure 10. The difference in the average score of the ability to face risk and change between the experimental and control class.

Based on Figure 11, there is a significant difference in the average posttest scores between the control and experimental classes. In the control class there was no change in the pretest and posttest scores concerning their ability to confront risk and adapt to change, remaining within the low-performance category. Conversely the

experimental class showed an increase in the average scores and witnessed a shift in student responses from the "disagree" to the "agree" category. These findings suggest that learning through the Rainwater Harvesting System project can enhance students' confidence in facing future

water scarcity due to climate change and the impact of human activities.

In the STEM learning, students have the opportunity to develop their abilities in facing risks and changes. STEM learning emphasizes problem identification, exploration, and experimentation, which involve taking risks and adapting to changes (Astuti et al., 2021; Prawvichien et al., 2018). In STEM learning, students are often confronted with complex challenges and problems (Indriyana & Susilowati, 2020; Kong & Matore, 2022). They are encouraged to think creatively, try new approaches, and take risks in seeking effective solutions. Through these experiences, students learn to face risks and perceive them as part of the necessary learning process to achieve desired outcomes.

Table 4. Changes in the design of the rainwater harvesting system prototype by group 1

Initial design	Final design

STEM learning encourages students to adapt and adjust their designs in response to changes. They learn to confront mistakes or unexpected outcomes and make modifications based on test results. This process helps students develop resilience to change and the ability to adapt to evolving situations. For example, in group 1, they made changes to their initial design due to issues encountered during testing, as seen in Table 4. They altered the composition of materials used in their prototype to achieve clearer rainwater. Students must be prepared to face problems that arise during conduct testing, and make improvements to ensure that the initial objectives are still met. Thus, through STEM learning, students have the opportunity to enhance their abilities in facing risks, taking initiative, and adapting to the changes they encounter in the learning process. The ability to confront risks and changes is a crucial skill in a constantly evolving and complex world (Withycombe, 2010).

CONCLUSION

Based on the conducted research, the rainwater harvesting system learning project has a significant influence on enhancing student anticipatory competency between the control and experimental groups. This method is believed to prepare students to face uncertainties by evaluating, predicting, establishing visions, assessing consequences, and considering various decisions before taking risks related to clean water and proper sanitation issues. The recommendation for this research is to considering the learning activity duration for the Rainwater harvesting system project, providing sufficient time for thorough exploration, redesigning prototypes, and receiving feedback. Adequate teacher preparation in Education for Sustainable Development (ESD) is crucial for successful implementation, and refining the assessment instrument to align with the curriculum content is essential.

REFERENCES

Aránguiz, P., Palau-Salvador, G., Belda, A., & Peris, J. (2020). Critical Thinking Using Project-Based Learning: The Case of The Agroecological Market at the "Universitat Politècnica de València." *Sustainability*, *12*(9). https://doi.org/10.3390/SU12093553

Armah, F. A., Yengoh, G. T., Ung, M., Luginaah, I., Chuenpagdee, R., & Campbell, G. (2017). The unusual suspects? Perception of underlying causes of anthropogenic climate change in coastal communities in Cambodia and Tanzania. *Journal of Environmental Planning and Management*, *60*(12), 2150–2173. https://doi.org/10.1080/09640568.2017.128 1797

Astuti, N. H., Rusilowati, A., & Subali, B. (2021). STEM-Based Learning Analysis to Improve Students' Problem Solving Abilities in Science Subject: a Literature Review. *Journal of Innovative Science*

Education, *9*(3), 79–86. https://doi.org/10.15294/jise.v9i2.38505

Brechin, S. R., & Bhandari, M. (2011). Perceptions of climate change worldwide. In *Wiley Interdisciplinary Reviews: Climate Change* (Vol. 2, Issue 6, pp. 871–885). Wiley-Blackwell. https://doi.org/10.1002/wcc.146

Creswell, J. W. (2014). *A concise introduction to mixed methods research.* SAGE publications. https://www.google.com/url?sa=i&rct=j&q=&esrc=s&source=web&cd=&ved=0CDYQw7AJahcKEwj4x_nXxc6AAxUAAAAAHQAAAAAQAw&url=https%3A%2F%2Fus.sagepub.com%2Fen-us%2Fnam%2Fa-concise-introduction-to-mixed-methods-research%2Fbook266037&psig=AOvVaw3j77Jfl3nVbRJIEpII8rN3

Creutzig, F., Roy, J., Lamb, W. F., Azevedo, I. M. L., Bruine De Bruin, W., Dalkmann, H., Edelenbosch, O. Y., Geels, F. W., Grubler, A., Hepburn, C., Hertwich, E. G., Khosla, R., Mattauch, L., Minx, J. C., Ramakrishnan, A., Rao, N. D., Steinberger, J. K., Tavoni, M., Ürge-Vorsatz, D., & Weber, E. U. (2018). Towards demand-side solutions for mitigating climate change. *Nature Climate Change*, *8*(4), 260–263. https://doi.org/10.1038/S41558-018-0121-1

Eliyawati, Widodo, A., Kaniawati, I., & Fujii, H. (2023). The Development and Validation of an Instrument for Assessing Science Teacher Competency to Teach ESD. *Sustainability (Switzerland)*, *15*(4), 1–14. https://doi.org/10.3390/su15043276

Feby Octafianellis, D., Sudarmin, S., Wijayanti, N., & Pancawardhani, H. (2021). Analysis of student's critical thinking skills and creativity after problem-based learning with STEM integration. *Journal of Science Education Research Journal*, *2021*(1), 31–37. www.journal.uny.ac.id/jser

Forsler, I. (2017). Researching Infrastructural Imaginaries in Education Through Future Workshops. *Researching Infrastructural Imaginaries in Education Through Future Workshops*. https://doi.org/10.4135/9781526442116

Ghari, M. (2018). Linear Temporal Justification Logics with Past Operators. *ArXiv*, *abs/1809.00167*. https://doi.org/

Gillingham, K., Nordhaus, W., Anthoff, D., Blanford, G., Bosetti, V., Christensen, P., McJeon, H., & Reilly, J. (2018). Modeling Uncertainty in Integrated Assessment of Climate Change: A Multimodel Comparison. *Journal of the Association of Environmental and Resource Economists*, *5*(4), 791–826. https://doi.org/10.1086/698910

Hansson, S. O. (2020). How Extreme Is the Precautionary Principle? *NanoEthics*, *14*(3), 245–257. https://doi.org/10.1007/S11569-020-00373-5

Hasanah, I. (2021). *Pengaruh Kegiatan Pengelolaan Limbah Rumah Tangga Pada Materi Pencemaran Lingkungan Terhadap Literasi Keberlanjutan Dan Kompetensi Antisipasi Siswa*. http://repository.upi.edu

Hoogendoorn, G., Sütterlin, B., & Siegrist, M. (2020). The climate change beliefs fallacy: the influence of climate change beliefs on the perceived consequences of climate change. *Journal of Risk Research*, *23*(12), 1577–1589. https://doi.org/10.1080/13669877.2020.1749114

Hunter, M. A., Aprill, A., Hill, A., & Emery, S. (2018). *Creative Criticality in the meenah neenah Cultural Arts Program (Critical Thinking)*. 47–60. https://doi.org/10.1007/978-981-10-7710-4_4

Indriyana, R. S., & Susilowati, S. (2020). The Effects of Model Project-Based Learning Approach on STEM (Science, Technology, Engineering, Mathematic) on Natural Science Learning to Junior High School Student's Critical Thinking Skills And Cooperative Skills at SMP N 1 Berbah. *Journal of Science Education Research*, *4*(2), 70–75. https://doi.org/10.21831/jser.v4i2.35717

Kabeyi, M. J. B. (2019). Organizational strategic planning, implementation and evaluation with analysis of challenges and benefits for profit and nonprofit organizations. *International Journal of Applied Research*, *5*(6), 27–32. https://doi.org/10.22271/ALLRESEARCH.2019.V5.I6A.5870

Kardoyo, Nurkhin, A., Muhsin, & Pramusinto, H. (2020). Problem-Based Learning Strategy: Its Impact on Students' Critical and Creative Thinking Skills. *European Journal of Educational Research*, *9*(3), 1141–1150. https://doi.org/10.12973/EU-JER.9.3.1141

Kartini, F. S., Widodo, A., Winarno, N., & Astuti, L. (2021). Promoting Student's Problem-Solving Skills through STEM Project-Based Learning in Earth Layer and Disasters Topic. *Journal of Science Learning*, *4*(3), 257–266.

https://doi.org/10.17509/jsl.v4i3.27555

Knap-Stefaniuk, A., & Ambrozová, E. (2021). Critical Thinking – the Basic Competency for Leadership in the 21st century. *Perspektywy Kultury*, *33*(2), 137–152. https://doi.org/10.35765/PK.2021.3302.10

Kong, S. F., & Matore, M. E. E. M. (2022). Can a Science, Technology, Engineering, and Mathematics (STEM) Approach Enhance Students' Mathematics Performance? *Sustainability*, *14*(1). https://doi.org/10.3390/SU14010379

Martuzzi, M. (2007). The precautionary principle: in action for public health. *Occupational and Environmental Medicine*, *64*(9), 569–570. https://doi.org/10.1136/OEM.2006.030601

Mehta, L., Adam, H. N., & Srivastava, S. (2019). Unpacking uncertainty and climate change from 'above' and 'below.' *Regional Environmental Change*, *19*(6), 1529–1532. https://doi.org/10.1007/S10113-019-01539-Y

Mentzer, N., Becker, K., & Sutton, M. (2015). Engineering design thinking: High school students' performance and knowledge. *2015 International Conference on Interactive Collaborative Learning (ICL)*, *104*(4), 417–432. https://doi.org/10.1002/JEE.20105

Mi, Z., Guan, D., Liu, Z., Liu, J., Viguié, V., Fromer, N., & Wang, Y. (2019). Cities: The core of climate change mitigation. *Journal of Cleaner Production*, *207*, 582–589. https://doi.org/10.1016/J.JCLEPRO.2018.10.034

Paprocki, K., & Huq, S. (2018). Shrimp and coastal adaptation: on the politics of climate justice. *Climate and Development*, *10*(1), 1–3. https://doi.org/10.1080/17565529.2017.1301871

Prawvichien, S., Siripun, K., & Yuenyong, C. (2018). Developing teaching process for enhancing students' mathematical problem solving in the 21st century through STEM education. *AIP Conference Proceedings*, *1923*. https://doi.org/10.1063/1.5019560

Puspita, A. S., & Aloysius, S. (2019). Developing student's critical thinking skills through implementation of problem based learning approach. *Journal of Physics: Conference Series*, *1241*(1). https://doi.org/10.1088/1742-6596/1241/1/012020

Rieckmann, M. (2012). Future-oriented higher education: Which key competencies should be fostered through university teaching and learning? *Futures*, *44*(2), 127–135. https://doi.org/10.1016/J.FUTURES.2011.09.005

Rios, M. M. M., Herremans, I. M., Wallace, J. E., Althouse, N., Lansdale, D., & Preusser, M. (2018). Strengthening sustainability leadership competencies through university internships. *International Journal of Sustainability in Higher Education*, *19*(4), 739–755. https://doi.org/10.1108/IJSHE-06-2017-0097/FULL/PDF

Scherak, L., & Rieckmann, M. (2020). Developing ESD competences in higher education institutions—Staff training at the University of Vechta. *Sustainability (Switzerland)*, *12*(24), 1–19. https://doi.org/10.3390/su122410336

Seddighi, H., Sajjadi, H., Yousefzadeh, S., López López, M., Vameghi, M., Rafiey, H., & Khankeh, H. (2022). School-Based Education Programs for Preparing Children for Natural Hazards: A Systematic Review. *Disaster Medicine and Public Health Preparedness*, *16*(3), 1229–1241. https://doi.org/10.1017/DMP.2020.479

Sobari, E. F. D., Hernani, H., & Ramalis, T. R. (2022). Critical Thinking Skills and Sustainability Conciousness of Students for The Implementation Education for Sustainable Development. *Journal of Science Education Research*, *6*(2), 75–80. https://doi.org/10.21831/jser.v6i2.52347

UNESCO. (2017). *Education for Sustainable Development Goals: Learning Objectives. Education for Sustainable Development. The Global Education 2030 Agenda.* http://www.unesco.org/open-access/terms-%0Ahttp://www.unesco.org/open-access/terms-use-ccbysa-en

Uwasu, M., Kishita, Y., Hara, K., & Nomaguchi, Y. (2020). Citizen-Participatory Scenario Design Methodology with Future Design Approach: A Case Study of Visioning of a Low-Carbon Society in Suita City, Japan. *Sustainability*, *12*(11). https://doi.org/10.3390/SU12114746

Wang, J., Hsu, J., Li, Y., & Gu, V. C. (2023). Confronting Current Crises and Critical Challenges of Climate Change. *International Journal of Sociotechnology and Knowledge Development*, *15*(1). https://doi.org/10.4018/IJSKD.318695

Wiek, A., Withycombe, L., & Redman, C. L. (2011). Key competencies in sustainability: A reference framework for academic program development. *Sustainability Science*, *6*(2), 203–218.

https://doi.org/10.1007/s11625-011-0132-6

Withycombe, L. K. (2010). Anticipatory Competence as a Key Competence in Sustainability Education. *Paper Knowledge . Toward a Media History of Documents*, *7*(2), 107–115. https://www.academia.edu/267695/Anticip atory_Competence_as_a_Key_Competence _in_Sustainability_Education

Xie, B., Brewer, M. B., Hayes, B. K., McDonald, R. I., & Newell, B. R. (2019). Predicting climate change risk perception and willingness to act. *Journal of Environmental Psychology*, *65*. https://doi.org/10.1016/J.JENVP.2019.101 331

Zizka, L., & Varga, P. (2020). Teaching Sustainability in Higher Education Institutions: Assessing Hospitality Students' Sustainability Literacy. *Journal of Hospitality & Tourism Education*, *33*(4), 242–257. https://doi.org/10.1080/10963758.2020.172 6771