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PROJECT EFFECTIVITY OF ADSORBENT FROM FOOD WASTE FOR HANDLING WASTEWATER AS A LEARNING STRATEGY TO LEARNING ACHIEVEMENT OF EDUCATION FOR SUSTAINABLE DEVELOPMENT AND INQUIRY ABILITIES

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Abstract

This study aimed to find the influence of the student's project on the achievement of learning of Education for Sustainable Development (ESD) and inquiry abilities. This study used a class of first-semester students (N=46) as a sample. Students carried out a research project to make adsorbents from food waste for handling wastewater. Some food wastes were selected as raw materials. Peer assessment and observation sheets were used as data-collecting methods. The results showed that students have succeeded and were excellent in the learning achievement of ESD and inquiry abilities because they were effective in using a holistic, participative, and transformative approach. Their learning achievement is in the high category but not all groups of students reach the above-average category because they have different abilities. This research concludes that the project of the manufacture of adsorbents from food waste for handling wastewater is effective as a learning strategy for producing inquiry abilities and achieving ESD goals. This inquiry project strategy should be used to increase student awareness about how to live sustainably.

Keywords: Adsorbent, , ESD, Food waste, Inquiry abilities, Inquiry project, Wastewater.

1. Introduction

The effectiveness of the adsorbent project from food waste for wastewater treatment is a learning strategy to achieve Education for Sustainable Development (ESD) and inquiry abilities from first-semester students[1]. Scientific inquiry refers to the search for knowledge or information by asking questions or seeking answers with methods depending on how evidence is collected and used [1]. ESD is a dynamic concept that includes a new vision of education. ESD seeks to empower people of all ages to take responsibility for creating a sustainable future. ESD is an effort to change behavior and lifestyle for positive community transformation [1,2]. Research in ESD advised focusing on strategies that promote sustainable behavior and involve citizens in decision-making adults [3].

ESD aims to help students everywhere obtain the knowledge, information, and skills needed to promote sustainable development [1-2]. For that, it must look for learning strategies that make students learn how to live more sustainably on this planet. Therefore, the learning model must shift from conventional to transformative [4]. Indeed, this required a bridge to connect ESD with transformative learning. However, current research on this learning strategy is still lacking.

Higher education students, with sustainability awareness, are agents of change. They are expected to support the achievement of sustainable development goals (SDGs). Therefore, ESD needs to be integrated into higher education programs to increase knowledge and attitudes [5].

The project of inquiry is one of the learning strategies proposed in this study. In Europe, it has disseminated an effective ESD integrated with Inquiry-Based Science Education as a learning strategy about food themes to 10 countries, but this activity is ongoing only for the professional development of teachers, or educators of science teachers not for students [1]. Adsorbents are used in industry to treat wastewater. However, the adsorbent used for this process is relatively expensive. Therefore, for ESD applications, cheaper and environmentally friendly adsorbents can be used. For example, the use of waste biomass from food waste is one of the best sources of materials [6].

Until now, many methods have been suggested for solving waste problems, but there are still disadvantages. For example, biological waste treatment has issues and disadvantages because its success highly depends on the activity and ability of microorganisms to degrade organic matter. Waste treatment by physical methods means it is considered less effective, especially in reducing heavy metals in solution. On the other hand, waste treatment using chemical methods is more effective due to direct action on its particles. However, these methods have limitations in the need for chemical-related materials as the main agent for reacting to the waste component.

For ESD, one of the best methods that are harmless and easily done in the conventional laboratory and the class is the adsorption process [7]. Adsorption is one of the effective ways to absorb hazardous content in liquid waste. Adsorption can act as chemical and physical treatments, depending on the type of adsorbent used in the experiment. The experiment procedure for adsorption is quite simple, which is conducted by introducing adsorbent into the wastewater. The waste component is absorbed onto the surface or into the pore of the activated adsorbent [8].

Some research has successfully found good performant adsorbents from some biomass particles, like calcium carbonate microparticles obtained from barred fish (*Scomberomorus spp*.) [9], carbon particle from Soursop (*AnnonaMuricata* L.) [10], carbon particle from Red Dragon Fruit (*Hylocereus undatus*) [11], carbon particle from Pumpkin (*Cucurbita maxima*) Seeds [12], proposed adsorbent biomass derived from bacteria, fungus, and algae for the removal of petroleum pollutants from water [13].

This study aims to find that a student project on making adsorbent from biomass waste is effective as a learning strategy that affects ESD learning achievement and inquiry skills. The method used in this study is the pre-experimental method. One class of freshmen students from varied disciplines of the Faculty of Mathematics and Natural Sciences Education, Universitas Pendidikan Indonesia were asked to find carbon particles from food waste. They apply the procedure of the prepared carbon particles as an adsorbent in the wastewater treatment.

The first novelty in this research is that several adsorbents from particles studied by students are innovative products. This is because students use food waste as raw material, non-toxic and harmless materials. Students also gain knowledge in innovating and developing new products from waste that contribute to the current need for a better environment and pay attention to sustainability [14]. Thus, their innovation regarding adsorbents from food waste is also the same as practicing student inquiry abilities. The second novelty is that investigating learning strategies for ESD is rare. Despite research that addresses the content and methods of ESD supported by the government in 20 countries in Europe, almost no research was done at the national level to evaluate the results from the implementation of the learning strategies [6]. The third novelty is to investigate Research with ESD on realistic conditions is very important. However, reports showing the application of ESD in waste management are rarely found. Therefore, for ESD applications, cheaper and greener adsorbents can be used. For example, biomass waste is one of the best candidates [15].

2. Literature Review

2.1. ESD and inquiry learning

Education for Sustainable Development (ESD) is a vision-seeking and reorienting of the education system that leads to sustainable learning. ESD aims to change the lifestyle of individuals and society to protect the environment and social equality. To achieve this goal, it is necessary to change [16] for curriculum and learning material in formal education at all levels; non-formal education, specifically for adults; Making the learning system more flexible and responsive to changing needs, providing new skills and opportunities; Increase the training of pre-service teachers and in-service teachers because they are the most powerful agents of change in the community so they can guide students on how to live sustainably.

ESD-oriented learning includes the main issues of SDGs in learning, such as climate change, risk conservation, biodiversity, poverty recovery, and sustainable consumption. This requires participatory learning methods to motivate and empower students to change as well as to act for sustainable development. Therefore, ESD supports competencies such as critical thinking, futuristic thinking, and collaborative decisions [1].

ESD cannot be implemented without science, because science plays a large role in supporting the three pillars of social, economic, and environmental. Science involvement, for example, is how commodities and products are produced, resources are used, or the environment is cleaned up. Bachman et al. used inquiry-based science education in implementing ESD because it developed the awareness and ability of young people to approach problems and imagine new scenarios through an active learning process of conceptualizing, planning, acting, and reflecting. This provides space for critical thinking to be combined with creative activities for the future [1].

2.2. The learning model using food waste as a source of adsorbent

In this inquiry learning model, students have been directed to identify problems about food waste in the community. They make observations in their milieu and daily life and analyse the situation until the problem is found. After they got the focus question, they searched for information to get a solution idea, then formulated the hypothesis to be tried. They identified the experimental variable, then designed the experiment and tested it until data had been obtained. Evidence will be obtained based on data analysis, that enables them to explain the rejection or acceptance of their hypothesis. So, they come to conclusions. Bachmann et al. said that inquiry is a method that develops the ability to be able to solve the complexity of the problem scientifically [1].

Biomass of food waste was initiated to be used as a raw material for making carbon particles. These particles are intended to be used as an adsorbent since many factories waste in polluted environments. Based on its purpose, the design in the production of carbon particles from food waste can be categorized as green chemistry [17].

Green chemistry knowledge is very important, in which it is not only for daily life but also for industry[18]. This knowledge can convert the way of thinking in the industry, especially when empowering and employing scientists and chemists to design processes to prevent pollution. Based on its nature, green chemistry is often referred to as sustainable chemistry. Watanabe used the concept of green chemistry as a platform to discuss sustainable development in the classroom. There are two principles of green chemistry: (1) to prevent the existence of waste rather than cleaning after it is forming, and (2) to make a process without reacting with certain chemicals, so it does not contain harmful chemicals.

2.3. Adsorbent from biomass particle

In this study, several students carried out a project to evaluate the conversion of food waste into valuable materials (carbon microparticles as adsorbents). Some food waste is not utilized properly (it only becomes household waste). The natural polymeric components present in food waste (namely, cellulose, lignin, and hemicellulose) can potentially be easily converted to carbon. The carbonization process uses high temperatures to break down the polymeric structure of the biomass and releases most of the non-carbon elements, especially oxygen, hydrogen, and nitrogen in liquid and gaseous forms, leaving a carbon component in the final product [9]. The chemical structure of several fruit peels or animal bones/shells contains mesoporous organic components. Calcination of mesoporous organics can produce mesoporous carbon materials. Indeed, it can provide a function to capture some materials/chemicals. The models of adsorption of carbon

particles from food waste are presented in Fig. 1 (a) and (b), which explain monolayer and multilayer adsorption, respectively.

Fig. 1. Absorption Models, Monolayer (a), and Multilayer (b)[11].

3. Method

3.1. Materials

The research method used the pre-experimental method, in which intervention was focused only on the experimental group. They received treatment to provide a task that was found adsorbent from waste food as an inquiry-based ESD (strategy learning) [19]. The inquiry-based ESD learning has been given to an integrated class that applies Mathematics, Science, Technology, and Engineering (MSTE).

3.2. Participant

Participants were selected from the freshmen students of the mathematics and natural sciences faculties at Universitas Pendidikan Indonesia. We treated the ESD program as integrated inquiry learning. The participants were selected from different disciplines of Mathematics (n =4), Mathematics Education (n =5), Chemistry (n = 4), Chemistry Education (n =6), Biology (n=4), Biology Education (n = 5), Physics (n=4), Physics Education (n=6), Science Education (n=4), and Computer sciences (n = 4) were combined in one class. The class consisted of 46 students and was divided into ten groups, with integrated group members from varied disciplines. Each group consisted of 4 to 5 students.

3.3. Stage of learning

The learning strategies applied in this research are the class was starting with an introduction to the ESD and SDGs concepts for understanding some issues in society. They were directed to learning and thinking critically by presenting local, national, and global issues. On this occasion, they also learned about how to conduct surveys, and how to collect and analyse data.

We applied four stages of inquiry learning in the classroom: the first is Invitation, which invites students into the problem through analysis of problems in everyday life with the theme of food. They must get problems from the closest community around campus about the food system. At this stage, students are given the task of conducting field observations, conducting surveys, and interviews with the intended object. From these results, they get facts and data that can be analysed as the background of the problem. They are directed to think systems, especially to relate their observations to the economic, social, and environmental aspects of the food system. The second stage is Problem Identification, students are asked to

formulate problems until they can focus on the problem. After that, they were asked to Design a Solution and sequence the steps of the solution to the problem procedure. In this process, students are guided intensely by the lecturer, often in the form of presentations and class discussions to get feedback from both friends and lecturers. The third stage was Conducting Experiments, by working in the laboratory, using tools, and materials, taking data, and analysing it. They were facilitated and guided by assistants. If there is something wrong in the process, redesign is carried out by correcting the error or correcting the procedure. The fourth stage, optimization is carried out by presenting the results in front of the class to lecturers and friends, so that they will get feedback to improve data processing or the process of concluding. Then at the end of the stage students are guided to make a report on their experiment by making a journal paper and guided to socialize the results of their experiments to the public through making videos.

Each stage was guided by worksheets and followed by the presentation and discussion to get feedback on every progress of experiment results. The assessment is carried out during the learning process, as well as the product or result. Performed both by teaching lecturers and assisted by assistants.

3.4. Assessment

The results are then measured in learning achievement from ESD and inquiry skills. ESD learning achievement indicators are holistic, participatory, and transformative approaches [1]. Indicators of the inquiry process consisted of getting an issue or problem in society, problem identification, planning the experiment, data recording, analysing experimental data, drawing a conclusion, and writing a scientific report. To find achievements in the aims of ESD, we get data from observation of their worksheet about getting problems, planning, testing, and redesigning, their presentation, video, and writing scientific reports. We used an interview to get data that was less captured through the questionnaire.

Peer assessment was employed to find inquiry skills. Indicators of the inquiry process consisted of identifying an issue or problem in society, problem identification, planning the experiment, data recording, analysing experimental data, drawing a conclusion, and writing a scientific report.

4. Results and Discussion

4.1. Adsorbent project as a learning strategy

Each group took different food waste as the basic material for making the adsorbent. Table 1 shows the raw material used in their project.

Table 1 shows that there was a different choice of raw material for students because the initial review for the problem was not the same. The important point is that they find the problems around their lives and relate them to aspects of sustainability. About 50% of students can complete their inquiry project perfectly until the adsorbent is tested on the curcumin solution as a wastewater simulation. They work compactly, diligently, and relatively quickly. Meanwhile, the rest could not complete the project perfectly. They are not incapable of being unable, but because of limited time and laboratory equipment. The collaborative process in groups is indeed a characteristic of inquiry learning because the collaboration

process is intended to maximize capacity and increase involvement in learning, which for ESD is more directed to sustainable development [20, 21].

Table 1. Adsorbent project from food waste: the subject per groups.

Groups	Raw materials used from food waste	Adsorbent
I	Kabocha Pumpkin Seeds (*Cucurbita maxima*. L)	carbon *
II	Soursop rind (*Annona Muricata* Linn.)	carbon *
III	*Tuna fish bones (Scomberonorus commersonii)*	calcium*
IV	Chicken eggshells	calcium
V	Peanut shells (*Arachis hypogea*)	carbon *
VI	Corn cob (*Zea mays*)	carbon
VII	Avocado peels (*Persea americana* mill)	carbon
VIII	Zalacca peels (*Salacca Edulis*)	carbon
IX	Dragon fruit peels (*Hylocereus polyrhizus*)	carbon
X	Pineapple peels (*Ananas comosus*)	carbon *

* Means that the inquiry process is carried out until the adsorbent is tested on the curcumin solution as a wastewater simulation.

4.2. Learning strategies affect to ESD achievement

Details observation as an example from group one, how they fulfil the inquiry learning and ESD by using Bachmann indicators [1]. This is an example of how the learning strategy fulfils to ESD indicator (see Tables 2 - 5).

Table 2. Evaluation activities and student learning that fulfil ESD: I. Key elements: The topic is developed about the dimensions of sustainability.

No.	Indicators	Score	Evidence	Data source
1.	Its environmental implications are identified and analysed	3	They identified that most of the liquid waste produced by food factories is discharged directly into rivers without being neutralized. They want to reduce Kabocha cake food waste, creating material to absorb and neutralize liquid waste such as tapioca flour factories, and textile factories. Thus, it can help maintain river cleanliness and maintain freshwater biota.	pr, and sr
2	Its social implications are identified and analysed	3	They consider if adsorbent substances from Kabocha waste were produced. They could create a good relationship between the factory owners with the surrounding community and a good relationship between the upstream and downstream river communities	wks, pr, and sr
3	Its economic implications are identified and analyses	2	They consider that the economic level of society remains low, and there are still many people who need jobs. If adsorbents are massively produced, it will increase the income and employment in society.	wks, pr, and sr
4	Local and global contexts and past/ present/future perspectives are considered	3	They consider that the substance is safe for the present and future because the adsorbent does not contain hazardous chemicals.	wks, and sr

Table 3. Evaluation activities and student learning that fulfil ESD: II. Key elements: The topic is developed using a holistic approach.

No.	Indicators	Score	Evidence	Data source
1.	Connections between dimensions of ESD are sought and different disciplines are involved	3	This group consists of various disciplines. They solve problems by considering social, economic, and environmental dimensions.	wks, pr, and sr
2.	The complexity of relationships between the natural environment and human activity is considered	2	They write that there is an accumulation of food production waste, the rivers get dirty/polluted, and the water biota decreases.	wks, pr, and sr
3.	There is awareness of uncertainty and its role in decision-making	2	Sometimes, they still seem not confident in expressing opinions or making decisions, but it is natural because they are still learning as a freshman.	pr

Table 4. Evaluation activities and student learning that fulfil ESD: III. Key elements: The topic is developed using a participative approach.

No.	Indicators	Score	Evidence	Data source
1.	The activities support reflection on our (individual and collective) role as citizens and as consumers of goods and services	2	They more to be sensitive to the environment around them reflects good citizens by care about the environment and social and economic conditions around it. As consumers of goods and services, they see the impact of wider use of goods and services including environmental, social, and economic friendliness.	itv
2.	Different points of view and opinions, and the conflicts which may arise, are considered	3	The research activity was carried out with a collaborative group, so the various points of view and opinions of each member of the group were considerable. This condition will lead to conflict but is still stable.	itv
3.	Responsibility towards the environment and the ‘common good is highlighted	3	They write that their product does not contain hazardous chemicals as a responsibility to the environment	wks, pr, and sr

Table 5. Evaluation activities and student learning that fulfil ESD: IV. Key elements: The topic is developed using a transformative approach.

No.	Indicators	Score	Evidence	Data source
1.	The activities stimulate critical reflection on issues	3	They consider various ways of treating organic waste and its effects. Starting from the biological, chemical, and physical processing, until finally choosing carbon particles as an adsorbent and green chemistry.	sr
2.	The activities promote creativity and proactive responses	3	They took the waste of cake production kabocha pumpkin as raw material and conducted the research.	wks, pr, and sr
3.	Attention is focused not only on knowledge, but also on values, lifestyles, and behaviors	3	They took Kabocha waste, which from useless became useful. In the lifestyle: their awareness, if the waste is not treated, will pollute the environment. In behavior: They were careful to make products by considering not using harmful chemicals that can damage the aquatic environment and sustainability in the future.	wks, pr, and sr
4.	Alternatives for change are to explore	3	They explore the Kabocha waste from useless became useful.	wks, pr, and sr
The total score = ((4x2) + (10x3))/42) *100 = 90.5%				

The score 0 = not detected, 1 = quite a bit detected, 2 = detected but must be through interviews, interpretation of discourse, there is help from others, or does not fully meet the criteria, and 3 = detected. interviews (itv), worksheets (wks), progress reports (pr), and scientific reports (sr).

Tables 2-5 present 4 number of ‘key elements that reference the Education of Sustainability Development. They can cover all the ESD criteria. The sum of the score is 38, equal to 90.5%. Their activities and thinking are aimed at economic, social, and environmental implications. They considered local and global contexts, and past/present/future perspectives too. For example, it refers to their questions: "What happens if this factory produces the cake for many years?", or “What happens if there are dozens of kabocha cake factories in Indonesia?”. They consider the adsorbent to be a safe solution for the present and future because it does not contain hazardous chemicals. These views pay attention to sustainable development and are important to apply in everyday life [17].

Evidence from no. 1-3 indicators in the first key elements showed how they consider social, economic, and environmental implications. They showed to think critically and logically to make the relationships dimension of ESD. They were using a holistic approach with considers all relevant causal variables of a problem and all social, environmental, and economic impacts of the solutions to achieve transformational systemic changes [22].

The second key element is the development using a holistic approach. Learning ESD requires the involvement of various disciplines that connect the natural environment and human activity. The involvement of various disciplines in this science is very meaningful in decision-making.

The third key element is developed using a participative approach, as citizens and as consumers of goods and services, they are sensitive to social, economic, and environmental issues in their daily life and want to change. They were sensitive to the community and environment in their milieu. They wrote that the low level of community welfare causes the lack of public knowledge and awareness of a healthy environment". This is the proof that showed responsibility towards the environment, and the 'common good' is the highlight. The participative approach implies not only engaging students' interest in theoretical lessons, encouraging group discussions and critical reflections, but also involving them in more practical activities, to connect academic achievement with real-life issues and to understand the impact of individual actions on the community [23].

Based on data in Tables 2-5, the fourth key element shows that the ESD topics developed using a transformative approach, and the activities were fulfilling with a transformative approach. They showed critical thinking, creativity, and proactive thinking and responses. They focused not only on knowledge but also on values, lifestyles, and behaviors. They choose the solution to make products by considering not using harmful chemicals that can damage the environment and the sustainability of the aquatic environment in the future. It appears how students perceive their learning experiences that offers not only changes in what they know or can do but also changes in how they know and how they understand themselves in their relationships with other humans and the natural world [5].

The result shows that some activities in the group like thinking, identifying, experimenting, making the decision, and drawing a conclusion are the way of their inquiry that contributed to the ESD. Some studies showed that inquiry-based learning is a compatible teaching method for fostering ESD in the classroom [24]. The key competencies of ESD were expected to enable active, reflective, and cooperative learning towards Sustainable Development, and this is an innovation in the field of Higher Education [25].

4.3. Learning strategy affects inquiry abilities.

Details observation as an example from group one, how they fulfil the inquiry learning by using Bachmann indicators [1]. This is an example of how the learning strategy fulfils to inquiry indicator (see Tables 6-10).

Tables 6-10 show from number 1 to 5 of key elements, and some numbers of indicators are a reference to the scientific inquiry process. The sum of the score is 43, equally with 89.6%. It means that the activities of the group, fulfilling all the indicators of inquiry learning, and the high category of effective inquiry teaching and learning. The group started by linking to a real situation through observation and interview with the head of the Kabocha cake production house. They found that each time Kabocha cake production produced a lot of trash. This waste will be thrown away into the water and polluted. Therefore, this was their reason for writing their report: Based on interviews from the house production of kabocha cakes in Lembang (West Java), they needed 90 kg of kabocha pumpkin every time production and will produce 18 kg of seed and skin waste. This food waste is not processed and will cause the accumulation of a lot of pumpkin trash. Thus, the students thought of how to make use of pumpkin rubbish into a useful product [11].

Table 6. An example of evaluation activities and student learning that fulfil inquiry of Kabocha pumpkin seed group: I. KE: Students engage in answering scientifically oriented questions.

No.	Indicators	Score	Evident	Data source
1.	A starting point is linked to a real situation	3	Students got the problem through field study and interviews with the Kabocha pumpkin Cake production house.	wks, pr, and sr
2.	Students consider what they already know and what they want to find out	3	Students know about the food system and sustainable food system and want to know about some food issues in society and to solve the problem.	wks, pr, and sr
3.	Productive questions are selected	3	Their first question is how the handling of kabocha pumpkin seed as food waste to be more functional. The second question is whether the carbon particles from kabocha seeds are effective as adsorbent wastewater.	wks, pr, and sr
4.	Students make predictions and conjectures	2	They said that the carbon particles from kabocha pumpkin seeds as an adsorbent effectively reduce the levels of waste in polluted water.	wks, pr, and sr

Table 7. An example of evaluation activities and student learning that fulfil inquiry of Kabocha pumpkin seed group: II. KE: Students give priority to evidence.

No.	Indicators	score	Evident	Data source
1.	Students decide what data to collect	2	They plan to collect data with guidance from nanoparticle experts.	wks, pr, and sr
2.	Students design the procedure for collecting data, and how to ensure accuracy	2	They plan to design procedures by guided nanoparticle experts.	wks, pr, and sr
3.	Students collect data	3	They were collecting data by guided nanoparticle experts and laboratory assistance.	wks, pr, and sr

Table 8. An example of evaluation activities and student learning that fulfil inquiry of Kabocha pumpkin seed group: III. KE: Students formulâtes explanation from evidence.

No.	Indicators	score	Evident	Data source
1.	Students analyse data and identify evidence	2	They analysed data by guided nanoparticle experts and laboratory assistants.	wks, pr, and sr
2.	Students formulate conclusions or explanations based on evidence	3	They were drawing a conclusion based on data	wks, pr, and sr
3.	Students answer the inquiry question(s) using this evidence	3	Their experimental results showed that the carbon particles of kabocha seeds were quite effective in absorbing curcumin molecules.	wks, pr, and sr

Table 9. An example of evaluation activities and student learning that fulfil inquiry of Kabocha pumpkin seed group: IV. Students evaluate their explanations.

No.	Indicators	Score	Evident	Data source
1.	Students check whether the evidence supports the explanations, and adequately answers inquiry question(s)	3	They have time with assistants and lecturers to discuss results and explanation	wks, pr, and sr
2.	Students check for any biases or flaws in their reasoning	2	When they tested the effectiveness of Kabocha carbon particle adsorption, they took three samples with the same mass.	sr
3.	Students check their results with those of their classmates	3	The class has time for a progress report through the presentation, to have feedback from peers and lecturers.	sr
4.	Students consider alternative explanations and link their results to scientific knowledge	3	They analysed and reported the results in a scientific report and using some references.	sr

Table 10. An example of evaluation activities and student learning that fulfil inquiry of Kabocha pumpkin seed group: V. Students evaluate their explanations.

No.	Indicators	score	Evident	Data source
1.	Students share their results and explanations through written, visual, or oral reports	3	They made papers as written reports and class presentations as oral reports, and even filed intellectual property rights, and obtained them.	sr
2.	Students explain why evidence is important, and link this to specific concepts or assumptions	3	They explained the results based on data and linked them to concepts and theory.	sr
	The total score = ((5x2) + (11x3)/48) *100= 89.6%			

Score: 0 = not detected, 1 = quite a bit detected, 2 = detected but must be through interviews, interpretation of discourse, there is help from others, or does not fully meet the criteria, and 3 = detected.

In this stage, they find the problem, which is how to handle kabocha pumpkin seed as food waste to be more functional. Their research aims to look at the effectiveness of the carbon adsorption power of kabocha seeds (fulfil number 1- 4 indicators). Then, their experimental planning, data collecting, data analysis, and taking references were guided by nanoparticle experts and laboratory assistance (fulfil the third key element). They redesigned their planning. The weakest steps were planning, solving the question, data collecting and analysing, and doing the lab work. Therefore, experts and assistant guidance were getting very helpful. Their weakness' is normal because they are still freshmen in higher education and come from various disciplines and different high schools. At this level, they experienced

a process of transformation or a transition from high school to college. Their adaptation to college began here.

This is evidence that "students explain why evidence is important, and link this to specific concepts or assumptions" fulfilled with the number 4 indicator. They wrote the results of the discussion as follows: The size of the adsorbent particles causes differences in the adsorption model of carbon particles. It is known that the smallest particle size of 200 μm has a higher adsorption capacity compared to particle sizes of 500 μm and 1000 μm. This is related to the surface area of the adsorbent, which can absorb the adsorbate in the curcumin solution. Another factor that can affect the level of adsorption is the clotting that occurs in the adsorbent particles. If the clot occurs, the surface of the adsorbent is not entirely open. It causes a reduction in the active surface area of the adsorbent, so the absorption process is ineffective, which results in reduced absorption capacity [11].

Based on this evaluation, they showed competencies in analysing and reporting the results in a scientific report and using some references. They can explain the results based on data and linked to concepts and theory. They were formulating conclusions or explanations based on evidence. This sentence is their conclusion, as they wrote in their report: The experimental results show that the carbon particles of kabocha seeds are quite effective in adsorbing curcumin molecules. Adsorption data on carbon particles of 1000 and 500 μ m size are better suited to the Langmuir isotherm model, while carbon particles of 200 μ m are more suitable to the Freundlich isotherm model. In general, this is due to differences in particle size affecting the aggregation of particles and the surface area that can interact with an adsorbate [11].

They can answer the inquiry question using this evidence through scientific investigations. They were more learner self-direction [26-28], although they still need to be guided in designing and conducting scientific investigations, as well as in the process of formulating explanations from the evidence. Likewise, using mathematics in all aspects of scientific inquiry, using appropriate tools and techniques to gather, analyse, and interpret data, and developing descriptions, explanations, and models using evidence.

4.4. Effectivity of the learning strategy on ESD and Inquiry achievement

This is ESD and inquiry achievement from our class (all the group) as a result of carrying out the project making adsorbent from food waste (see Table 11).

Table 11 shows that students have succeeded in achieving excellent inquiry and learning achievement in ESD (above a score of 80). This is indicated by the achievement of all aspects of the approach and dimensions of sustainability above a score of 85 in the high category. Of the ability to carry out the scientific inquiry process of students, 50% is above average, the rest is below average but still in the high category. Not all groups of students reach the above-average category due to limited equipment and laboratory constraints. In addition the attitude of students who are less alert so that they cannot compete with their friends who are more alert and compact. So, there is a collaboration factor that affects student performance. In this case, social performance is not only sharing ideas and being willing to change thoughts but also an agreement to work together to help each other. The existence of a reciprocal relationship, in line with the results of the study of Mercer, Littleton, and Linnell, that thoughts in groups, this clashing of ideas causes a strong inter-subjective relationship within the group [30].

Table 11. ESD and student inquiry achievements.

Group	I	II	III	IV	V	VI	VII	VIII	IX	X	MEAN
ESD	**90.5**	95.2	95.2	95.2	95.2	**92.8**	**92.8**	**92.8**	95.2	95.2	94.5
Inquiry	89.6	89.5	91.6	**85.4**	91.6	**85.4**	**87.5**	**87.5**	**85.4**	91.6	88.7

The value in bold is below the average.

The achievement of the ESD category according to [1] of all groups is at a very high category achievement (Table 11). This happens because students can develop food themes in the aspect of sustainability and link all problems and solutions in social, environmental, and economic aspects, as well as consider local and global contexts both today and in the future.

Concerning the social aspect, students from group five wrote: "If the adsorbent product can enter the market, it can reduce disputes between residents because of dirty water". As for environmental aspects, students wrote in one of the student worksheets: "… this adsorbent from fish bone waste mackerel can reduce textile waste (group 3)", or students identified that the treating waste by seeds Kabocha adsorbent will negate the existing waste to protect the earth from waste (group 1)". While the economic aspect in general, students said that: "Processing food waste into adsorbent can increase employment, income and reduce unemployment".

ESD for this food theme was developed with a holistic, participatory, and transformative approach (Fig. 2). We could find that the achievement for each of these indicators is high.

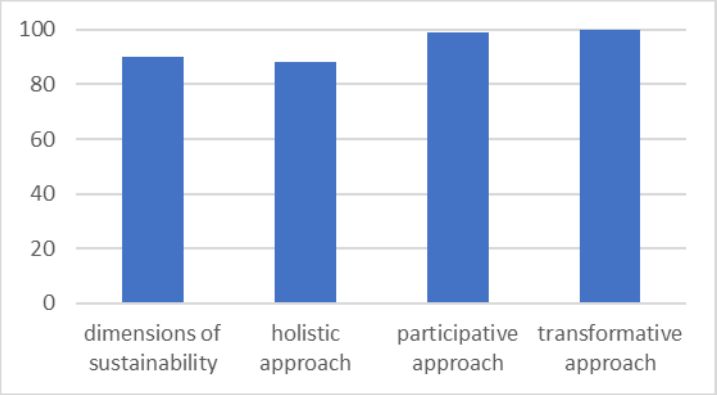

Fig. 2. Achievement for each indicator of ESD.

For a holistic approach, generally, students carried out research based on studies from various disciplines. In solving problems aspect, they also look at it from environmental, social, and economic aspects [1]. They also consider the complexity of the relationship between the natural environment and human activities, in this case, students take problems that come from human activities and look for solutions that are beneficial to the environment, namely the manufacture of adsorbents from food waste. An example, students take a problem from the observation that pineapple peels are abundant but not processed, finally it is only disposed of to the final landfill. They thought about how to use this waste to have added value, so they took it as an adsorbent idea [31]. All of the groups had the same idea because

they looked at videos about the usefulness of adsorbent on the stage invitation of inquiry learning.

Another aspect contained in, it is the awareness of uncertainty and its role in decision-making. Students realize that the results of their designs are still in the form of predictions, so they must be tested by conducting experiments. For students, experimental data is very helpful for making decisions. The holistic approach is very beneficial because it makes students critical, confident, and independent [32]. This approach also aims to make learning a process of self-improvement and to recognize the individual needs of learners in interacting.

The ESD for the food theme was developed with a participative approach. Several aspects include first, learning activities reflect the role of students (both individuals and groups) as citizens, as well as consumers of goods and services. In this study, as consumers of the food that they eat every day and based on their observations, they found that the producers of boiled peanuts treated their waste poorly, so they were moved to make adsorbents from peanut shell waste. Another group found the fact that corncob waste was not treated but only burned or thrown away, they assumed that if this continued, there would be a bad impact on the environment. The second aspect considers different points of view and opinions, as well as conflicts that may arise. Based on the results of the researcher's observations and interviews, there are always differences of opinion when making decisions in groups, but they can still handle the problem by discussion. Third, aspects of their project highlight the responsibility to the environment for the 'common good'. In general, students show their responsibility to the environment by looking for ways to treat waste that has a good effect on the environment, namely using adsorbents from food waste to reduce waste in the waters.

In addition to the participatory approach, ESD for the food theme also develops a transformative approach. The indicators consist of first, learning stimulates critical reflection on the problem [32]. This aspect was done well by students because from the observations it was recorded that at first students suggested several alternatives to deal with food waste, For example, group 8 chose a solution to make *Salacca edulis* skin to be made adsorbent after going through various considerations, which in everyday life The bark of *S. edulis* has no value and is simply thrown away as organic waste, but based on a literature review, it turns out that the content of this bark has silica which is good for adsorbent materials. Second, learning activities promote creativity and proactive responses. In this case, students (group 3) collect tuna fish bones (*Scomberonorus commersonii*) which initially did not have a special function and were never even used or projected as adsorbents in the laboratory, for research to produce products that are suitable for use. useful and effective as an adsorbent. Third, focus attention not only on knowledge, but also on values, lifestyle, and behavior. Learning activities besides aiming to enrich knowledge, the research carried out has other advantages. For example, group 1 wrote for the value aspect: they took Kabocha waste, which was originally useless to become useful, while for the lifestyle aspect: their awareness, that if the waste is not treated, will pollute the environment, while for Behavioral aspect: they are careful to make products by considering not using harmful chemicals that can damage the aquatic environment and its sustainability in the future. Fourth, explore alternative changes. In this case, students (group 6) explore how to process corncob waste that is not useful into an adsorbent that it has useful

5. Conclusion

The purpose of this study was to find the influence of the student's project on ESD and inquiry learning achievements. Students successfully carried out the project to make adsorbent from food waste for handling wastewater. The results showed that students have succeeded in achieving excellent inquiry and ESD because they are quite effective in using a holistic, participatory, and transformative approach. This research concludes that the project of the manufacture of adsorbents from food waste to handling wastewater is very good as a learning strategy to produce inquiry abilities and achieve ESD goals. The obstacle that occurs in this learning is that students still need to adapt a lot to work patterns in the laboratory, introduction of tools, availability of tools, and assistance. Students are still not familiar with inquiry work patterns, so lecturers and assistants must be patient in guiding students. So as a suggestion for users of the learning model in higher education, to carefully carry out each stage of learning, with careful preparation in the content of the material for the themes taken, as well as worksheet learning media devices as well as handouts and assessment instruments. For future research, it is recommended that the theme of inquiry projects be more challenging but can still be done by first-year students, for example, the themes of environment, health, marine, and others.

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