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Comparing project-based learning and problem-based learning to foster 21st-century learning skills in agricultural seaweed product

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Abstract

This study examined the effect of 1) learning strategy [project-based learning (PjBL) and problem-based learning (PBL)] on the ability of seaweed product diversification; 2) 21st-century learning skills [critical thinking, communication, collaboration and creativity (4Cs)] on the ability of seaweed product diversification; and 3) the interaction between PjBL, PBL and 4Cs on the ability of seaweed product diversification. This study was a quasi-experiment with a 2 × 4 factorial design, namely two learning strategies (PjBL and PBL) × four types of 21st-century learning skills. The research subjects were college students of a public university (n = 70). Data were analysed using the two-way analysis of variance. The results indicated that (1) there were significant differences in students' ability to diversify seaweed between groups which were taught with PjBL and the one with PBL, (2) there were differences in the ability of students' to diversify seaweed between the ones in the groups with different 21st-century learning skills and (3) there was an interaction between learning strategies and 21st-century learning skills towards the ability to diversify seaweed products. This study indicates that the implementation of PjBL brings a better effect compared to the implementation of PBL in fostering 21st-century learning skill.

Keywords: Project-based learning; problem-based learning; 21st-century learning skills.

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1. Introduction

Vocational education learning, especially agricultural technology education learning, needs to provide examples of problem-solving in real life (Kricsfalusy, George & Reed, 2018; Lucas, Spencer & Claxton, 2012). The learning that can develop the ability to solve problems and manufacture real products are project-based learning (PjBL) (Bell, 2010; DeMink-Carthew & Olofson, 2020; Smith & Rayfield, 2016) and problem-based learning (PBL) (Diegel, Nordin & Motte, 2019; Phungsuk, Viriyavejakul & Ratanaolarn, 2017). A few studies have evaluated PjBL in agricultural technology learning (Kibett & Kathuri, 2005; Smith & Rayfield, 2016), as well as PBL (Abbey, Lord, Dowsett & Sullivan, 2017; Parr & Edwards, 2004). However, these studies tend to study the two approaches separately. There is no research that combines PjBL and PBL strategies in one study, which examines issues related to seaweed products diversification. As a result, there are not many scientific publications related to learning strategies in agriculture in Indonesia; so, this research can be regarded as a research pioneer in this field.

In seaweed learning, there are two abilities that must be emphasised, namely the ability to formulate problems and the ability to make artefact products (Helle, Tynjala & Olkinuora, 2006). Both aspects can be achieved by integrating PBL and PjBL learning strategies (Prince & Felder, 2006). Although the two approaches are different, both require some skills that must be mastered by students so that the learning objectives can be achieved. The skills referred to in this case are critical thinking skills, creative, collaborative and communication skills (Alismail & McGuire, 2015; Amran, Perkasa, Satriawan, Jasin & Irwansyah, 2019; Zabit, 2010). These four skills are generally known as 21st-century skills, which are abbreviated as 4Cs (Romero, 2016). This research not only integrates the PjBL and PBL strategies in learning, but also focuses on examining the 4Cs' skills which are the condition variables in the application of the learning strategy. As a variable of learning conditions, 21st-century learning skills are different for each student. Therefore, measuring these skills at the beginning of learning is believed to facilitate the acquisition of the ability of seaweed product diversification.

There are several previous studies that have reviewed and compared PjBL and PBL methods in learning. Affandi and Sukyadi (2016) reviewed PjBL and PBL for EFL students' writing achievement at the tertiary level. However, the study aimed to 1) examine the effect of PjBL and PBL on writing achievement; 2) detect differences in writing skills in groups taught with PjBL and PBL; and 3) obtain students' perceptions of writing skills based on PjBL and PBL methods. The results showed that the PjBL method was more influential in training students to learn through the problem-solving process by developing critical thinking, building social and cooperative skills and increasing students' motivation and enjoyment in writing compared to the PBL method.

Another research conducted by Anazifa and Djukri (2017) aimed to examine the effect of PjBL and PBL in terms of students' creativity and critical thinking and differences in the effects of PjBL and PBL based on creativity and critical thinking. The results show that (1) PjBL and PBL affect students' creativity and critical thinking; (2) there is a difference in the effect of PjBL and PBL on students' creativity; and (3) there is no difference in the effect of PjBL and PBL on students' critical thinking. Another research conducted by Husna and Gultom (2019) aimed to examine the effect of PjBL and PBL on higher order thinking skills. The results showed that PjBL and PBL have the same effect in increasing higher order thinking skills.

PjBL and PBL are two types of learning strategies that are equivalent and are based on constructivist learning theory. Not many studies have examined both of them and placed them as experimental studies on the learning of seaweed, especially on seaweed product diversification.

Besides, there has not been much research integrating these two types of learning strategies with 21st-century learning skills. Therefore, the objectives of this study are to examine 1) the influence of PjBL and PBL on the learning ability of seaweed product diversification; 2) the influence of 21st-century learning skills on the learning ability of seaweed product diversification, and 3) the interaction pattern between PjBL and PBL with 21st-century learning skills on the learning ability of seaweed product diversification.

1.1. Concept of PjBL and PBL

Based on various concepts, PjBL is defined as a learning model that assists students in solving real problems – critical, creative and communicative. PjBL is based on the learning and teaching paradigm that emphasises social and constructivist dimensions in carrying out teaching and learning activities (Gu & Wang, 2006). The application of PjBL in the learning process becomes very important to improve students' ability to think critically and to be independent in learning. As a constructivist learning, PjBL facilitates students to learn in the real situation, so that they can gain permanent knowledge. PjBL is a model that can organise projects in learning (Gulbahar & Tinmaz, 2006). PjBL provides opportunities for student-centred learning systems, more collaboration, students are actively involved in completing projects independently, working together in teams and integrating real problems (Paris & Paris, 2001; Rashotte, MacPhee & Torgesen, 2001).

Some earlier studies showed that PjBL is important to be applied. Johann et al. (2006) reported that 90% of the students who followed learning which implemented PjBL were optimists who were able to implement PjBL in the working world and believed that they can increase their learning achievements. Besides that, a survey study by Lasonen and Vesterinen (2000) showed that 78% of the students believed that curriculum with PjBL basis can prepare a student to enter the working world because they not only study about theory but also carry out practices in the field. The effectiveness of this PjBL was compared with PBL, which based on some references and implementations, these two learning strategies have a similar position in constructive learning strategies. Besides that, the effectiveness of learning of seaweed product diversification was examined under various learning conditions with different 21st-century learning skills. In this context, the skills of 21st-century learning that would be examined include critical thinking, communication, collaboration and creativity.

PBL as a control variable in this study is designed to develop ways of thinking, problem-solving, intellectual skills, learning to act like adults through real situations or simulations and to become independent learners (Arends, 2015). Wheeler, Kelly and Gale (2005) have defined PBL as learning based on thinking through real-life problems. PBL can improve technical skills, creative thinking and good social behaviour of students; so it is increasingly applied in various disciplines (Hoidn & Karkkainen, 2014), included in the learning of seaweed product diversification. Abbey et al. (2017) applied a PBL strategy in horticultural production learning. The results show that PBL methods have better results in improving learning outcomes compared to traditional learning, students are more motivated and take initiative in making decisions.

1.2. 21st-century learning skills

In various literatures, it is explained that 21st-century skills are knowledge, skills, work habits and character traits that are believed to be significantly helping students to learn, work and live successfully in a variety of environments in the 21st century (Moyer, 2016; Queensland Curriculum and Assessment Authority, 2015; Rotherham & Willingham, 2009). In another perspective, the 21st-century skills include

several skills, namely skills to communicate, to think critically, to build networks, to collaborate, to solve problems, to create, to innovate, to analyse and to evaluate (Santos, 2017).

In this study, four 21st-century skills were examined, namely critical thinking, communication, collaboration and creativity. Critical thinking skills are used when the information obtained requires more complex reasoning and the ability to synthesise and analyse (Hixson, Ravitz & Whisman 2012). Communication skills have become one of the most needed 21st-century learning skills. The essence is that students have sensitivity in transmitting information into valid and useful data. When working in teams, the ability to process important information is applied so that effectiveness in working can be effectively transformed. Hixson et al. (2012) identified communication skills as the ability to use data and media from various sources, both oral and written, to convey the message effectively. Collaborative skills are needed when students work in the real world. When in the learning process, students need a learning design that teaches the collaborative process of working in teams. The process of making diversified seaweed products requires collaborative work. It is intended that individuals with different expertise in the team can complement each other (Kym & Hvolby, 2010).

PjBL and PBL as method variables and 21st-century learning skills as moderating variables are intended to increase the internal validity of the research design. In addition, these two variables are assumed to influence in achieving the ability to seaweed products diversification as learning outcome variables. Thus, the effect of learning strategies and 21st-century learning skills on the learning outcomes of seaweed products diversification needs to be examined

2. Research Method

2.1. Research design

This study employed the quasi-experimental design to find out the relationship between variables (Gall, Gall & Borg, 2003; Salkind, 2012). All groups in this study were given treatment, which in this case, the first group studied with PjBL while the second one was treated with PBL strategy. Therefore, the design of this experimental study was one of non-equivalent control group design versions (Tuckman & Harper, 2012) a 2 × 4 factorial.

2.2. Sample

The research subjects were students from the Agricultural Technology Education Department in a public university in the fifth semester of the academic year 2019–2020. The total number of students was 70 divided into classes A and B with 35 students each. Class A was taken as the experimental group, while class B was the control group. It followed one of the quasi-experimental characteristics that divide subjects not on a random basis, which in other words, the subjects were grouped according to the existing classes (Salkind, 2012).

2.3. Research procedure

The experiments were carried out by performing scenarios of the two learning strategies. Both control and experimental classes were given the same treatment, which was to develop a paper about various seaweed product diversifications. The PjBL consisted of five groups with five different seaweed product diversifications. Similarly, the PBL also made a paper with the same topic in the formerly mentioned group. The instruments used in this study were grouped into two categories, namely (1) the instrument to measure the 21st-century learning skills and (2) the instrument to assess the skills of seaweed product diversification. The first instrument adapted 21st Century Competencies (The Ontario Ministry of Education, 2016), which consists of four skills namely: critical thinking, communication,

collaboration and creativity. The second instrument used to measure the seaweed product diversification was in the form of a test, which assessed students' knowledge about seaweed diversification. Data were collected with the following steps: (1) conducting a test on the 21st-century learning skills, (2) giving a pre-test to measure the knowledge of seaweed diverse products, (3) implementing a learning intervention (experimental) and (4) providing a post-test.

2.4. Data analysis

The analysis requirements test used data normality test and variant homogeneity tests. The data normality test employed the Kolmogorov–Smirnov technique, while the variant homogeneity test utilised the Levene test. The data normality test and the data homogeneity test aimed to fulfil the parametric assumptions. The data were analysed using parametric statistical analysis with the two-way analysis of variance and the 2 × 4 factorial variance analysis had the purpose to test the research hypothesis

3. Finding

3.1. The description of 21st-century learning skills

The description of data on the measurement of the 21st-century leaning skills using the 21st Century Competencies instruments on two research subjects is presented in Table 1. Table 1 shows that the group implementing the PjBL had a smaller number of student with critical thinking skills, which was only 14.29%, while the creativity possessed by 34.29% of the students was the highest number. Similar to the PBL group, students with critical thinking skills had the smallest number, which was only 14.20% of them. The skill possessed by the largest number of students was collaboration as there were 34.29% who seemed to have the skill.

Table 1. The description of the 21st-century learning skills

21st-century learning skills	PjBL(%)	PBL (%)
Critical thinking	14.29	14.29
Communication	22.86	25.71
Collaboration	28.56	34.29
Creativity	34.29	25.71
Total	100	100

Data about the students' understanding on seaweed diversified products after being taught with PjBL and PBL are presented in Table 2. Table 2 indicates that communication is the 21st-century learning skills which obtained the highest score in the group of PjBL with an average score of *M* = 39.25. Other skills (collaboration, critical thinking and creativity) had balanced scores. On the other hand, the group implementing the PBL approach showed that the skill with the highest score was creativity (*M* = 38.44).

Table 2. The results of the descriptive analysis of data about the understanding on seaweed diversification products

Learning strategies	21st-century learning skills	Mean	Standard deviation	*N*
Project-based learning	Critical Thinking	38.80	1.095	5
	Collaboration	38.90	0.994	10

	Communication	39.25	1.035	8
	Creativity	38.58	1.311	12
	Total	38.86	1.115	35
Problem-based learning	Critical Thinking	37.20	1.095	5
	Collaboration	34.75	3.251	12
	Communication	37.33	1.414	9
	Creativity	38.44	1.667	9
	Total	36.71	2.641	35
Total	Critical Thinking	38.00	1.333	10
	Collaboration	36.64	3.230	22
	Communication	38.24	1.562	17
	Creativity	38.52	1.436	21
	Total	37.79	2.283	70

3.2. The effect of learning strategies (PjBL and PBL) on the ability of seaweed product diversification

The results of the hypothesis test show the effect of learning strategies (PjBL and PBL) on seaweed product diversification ability, the effect of 21st-century learning skills on seaweed product diversification ability and the effect of interactions between learning strategies and 21st-century learning skills on seaweed product diversification ability. In detail, the results of the hypothesis test are summarised in Table 3. Table 3 shows that there was a difference in the understanding on seaweed diversification product between students in the gro*up of students taught using PjBL strategy and students in the group treated with PBL strategy* ($p \leq 0.05$). The average score of students' understanding on seaweed products diversification after being taught using the strategy of PjBL was 38.86, which was significantly higher that the results found in the group treated with PBL, which was only 36.71. This shows that the PjBL strategy has a higher effect than the PBL strategy on seaweed product diversification ability.

Table 3. The results of the hypothesis test

Source	Type III sum of squares	df	Mean square	*F*	Sig.
Corrected model	160.397[a]	7	22.914	7.125	.000
Intercept	90707.475	1	90707.475	28205.501	.000
Learning strategies	60.092	1	60.092	18.686	.000
21st-century learning skills	35.518	3	11.839	3.681	.017
Learning strategies * 21st-century learning skills	43.419	3	14.473	4.500	.006
Error	199.389	62	3.216		
Total	100303.000	70			
Corrected total	359.786	69			

[a]*R* Squared = 0.446 (Adjusted *R* Squared = 0.383).

3.3. The effect of 21st-century learning skills on the ability of seaweed product diversification

Table 3 shows that there was a significant difference on students' understanding on seaweed products' diversification between students who had the 21st-century learning skills, which includes

critical thinking, communication, collaboration and creativity in the Agricultural Technology Education Department in a public university ($p < 0.05$). The 21st-century learning skills with the highest score in the PjBL group are communication skills, with a mean score of 39.25 (Table 2). This means that in the learning of seaweed products diversification with the PjBL strategy, the most necessary 21st-century learning skills are communication skills which consist of listening, digital literacy and communication in team. On the other hand, the other 21st-century learning skills in general have an almost equal mean score, namely critical thinking (38.80), collaboration (38.90) and creativity (38.58). This average score shows that in PjBL strategy, students have 21st-century learning skills that are evenly distributed in critical thinking, collaboration and creativity. Table 2 shows that 21st-century learning skills with the highest score in PBL is creativity (38.44). It shows that in learning to make diversified processed seaweed products, 21st-century learning skills that most develop in students are creativity, which consists of the ability to develop, to elaborate, to analyse and to evaluate ideas. Other 21st-century skills in PBL strategy, namely critical thinking skills (37.20) and communication (37.33), have almost the same score, except for collaboration abilities (34.75), which had a relatively low score. This shows that students on PBL strategy have 21st-century learning skills that are evenly distributed in critical thinking and communication and lower in collaboration.

Based on the results of the post-test using Tukey's test shown in Table 4, it was found that the collaboration and communication skills of students differed significantly (p <0.05). In addition, 21st-century abilities that differed significantly were creativity and collaboration (p <0.05).

Table 4. Post-test results using Tukey's test on 21st-century learning skills.

(I) 21st-century learning skills	(J) 21st-century learning skills	Mean difference (I–J)	Std. error	Sig.	95% confidence interval	
					Lower bound	Upper bound
Critical thinking	Collaboration	1.36	0.684	0.201	−0.44	3.17
	Communication	−0.24	0.715	0.988	−2.12	1.65
	Creativity	−0.52	0.689	0.872	−2.34	1.30
Collaboration	Critical thinking	−1.36	0.684	0.201	−3.17	0.44
	Communication	−1.60*	0.579	0.037*	−3.13	−0.07
	Creativity	−1.89*	0.547	0.005*	−3.33	−0.44
Communication	Critical thinking	0.24	0.715	0.988	−1.65	2.12
	Collaboration	1.60*	0.579	0.037*	0.07	3.13
	Creativity	−0.29	0.585	0.960	−1.83	1.26
Creativity	Critical thinking	0.52	0.689	0.872	−1.30	2.34
	Collaboration	1.89*	0.547	0.005*	0.44	3.33
	Communication	0.29	0.585	0.960	−1.26	1.83

3.4. Interaction patterns between learning strategies and 21st-century learning skills on the ability of seaweed product diversification

Table 3 shows that there was an interaction between the learning strategy and the 21st-century learning skills (critical thinking, communication, collaboration and creativity) and the students' understanding on seaweed products diversification at Agricultural Technology Education Department in a public university ($p < 0.05$). The interaction pattern between the learning strategy and the 21st-century learning skills and students' understanding of seaweed diversification products is shown in

Figure 1. Figure 1 shows that the average ability of seaweed product diversification of students in the group implementing PjBL methods was higher than that of students in the group using the PBL model. The four lines touch each other so that it can be regarded that there is an effect of the interaction between the learning strategies and the 21st-century learning skills on students' understanding of seaweed product diversification.

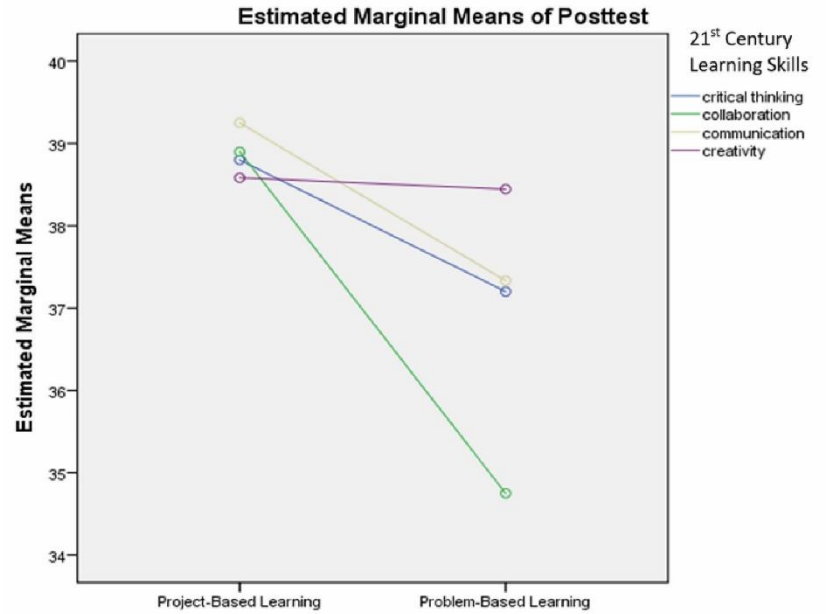

Figure 1. Interaction patterns between learning strategies and 21st-century learning skills on the ability of seaweed product diversification

4. Discussion

The implementation of PjBL in the learning practices which targets the improvement of competency is a must. Various real practices have sufficiently provided empirical evidence that PjBL is effective in accommodating the learning skills. Esche (2002) reported that one of the factors advising the implementation of the PjBL is due to its ability to provide a learning background that can bring the real situation of the field in learning. In its application, one of the characteristics of PjBL is the existence of learning groups that allow students to work collaboratively, to communicate with each other to provide creative ideas and thoughts, to solve a problem and to communicate interactively with other students in constructing new knowledge (Asan & Haliloglu, 2005; Blumenfeld, Fishman, Krajcik, Marx & Soloway, 2000; Marchaim, 2001; Yildirim, 2010).

In PjBL strategies, instructors act as facilitators for design learning activities and provide advice that substantially encourages the development of meaningful learning processes. The meaningful learning process is learning that is developed based on the concept of constructivism which emphasises students as "active students", the central regulator of activities in mediating and controlling learning (Lasonen & Vesterinen, 2000). Constructivism characterises learning as forming meaning and developing thought. In short, PjBL provides a conducive learning environment so that it can help improve student skills in accordance with the constructivist learning traits. Thus, learning activities are not just learning to accept and memorise concepts, but rather to interpret a concept.

This research found that there are differences in the ability to diversify seaweed products between groups of students who were taught using PjBL strategies and groups of students treated with PBL in the Agricultural Technology Education Department. The effect of the PjBL strategy compared to PBL strategy was due to the ability of the PjBL strategy to provide learning opportunities for students to work in teams, to plan, to organise, to negotiate and to convert thoughts and ideas into real work that is projected experimentally. On the contrary, in PBL, the opportunity to identify, analyse and solve problems in groups and activities to construct knowledge and explore information sources is synthesised in groups and set forth in the form of innovative and reflective concepts undertaken by the team, but not converted into an experimental project. This aspect distinguishes it from PjBL. When the synthesised concepts are outlined in the form of practical work such as making and designing products, then in this case, PBL only reaches the stage of product development concepts. The findings of this study are in line with previous researches which found that PjBL leads to the achievement of knowledge competencies and skills in working procedures (Esche, 2002; Grey & Antonacopoulou, 2004; Sabry & Baldwin, 2003).

The effectiveness of this research is that the learning atmosphere can encourage project groups to take place vigorously, and through observations, students seemed to enjoy learning methods that were developed based on PjBL scenarios. Students critically express ideas in collaborative groups, start from constructing essential questions, planning a project, making project implementation schedules, working on, analysing, evaluating project results, to exchanging information between groups through the presentation of project results about seaweed products diversification. In the presentation session, each group is trained to think critically in responding to problems and provide solutions to each other. The most important thing from this process is how students communicate ideas into a unity such as creativity, communication, critical thinking and collaborative as a characteristic of 21st-century learning skills.

Here are the essences of meaningful learning. PjBL provides chances for students to create and carry out a project to find new information from various sources of information. In this context, PjBL helps investigations that lead to solving more contextual problems in society. The products developed in the learning of seaweed products diversification are ice cream, red nori food, traditional food of *terang bulan* and *cendol* and pudding. From the theory perspective, 21st-century learning skills in the form of critical thinking, collaboration, communication and creativity have influence on the ability of seaweed product diversification. The results of hypothesis testing indicated that there were differences in the ability of seaweed products diversification between students who had different 21st-century learning skills. In other words, 21st-century learning skills have a significant influence on the ability of seaweed product diversification.

In certain cases, sometimes students who have communication and collaboration skills can superiorly influence the ability of seaweed product diversification compared to students who have critical thinking and creativity learning skills on the same learning strategy. Likewise, with the learning skills of creativity and communication, sometimes students who have both learning skills are superior to students who have critical thinking and collaboration learning skills. Students with critical thinking skills have the ability to use a number of reasoning according to the situation, think systematically, linking one part with another so that they are able to produce products (Lestari et al., 2019; Sahril et al., 2021). Students with collaboration skills are able to work in teams effectively and value team members' contributions based on their individual responsibilities. Students with communication skills are able to communicate effectively, both verbally and non-verbally, and in a variety of environments. Students

with creativity ability are able to generate new ideas, elaborate and evaluate their own ideas to explore better learning opportunities (National Education Association, 2020).

Ability of seaweed product diversification is easier to be mastered by students who have communication and collaboration skills. This is because the characteristics of students with communication and collaboration skills are in accordance with the competencies needed in the seaweed product diversification, namely effective cooperation, mutual understanding and communicative interactions. The ability to make processed seaweed products such as ice cream, red nori food, traditional food of *terang bulan* and *cendol* and pudding is in higher cognitive domain. Thus, in making diversified seaweed products, it requires the ability to work in teams, take responsibility, assign roles and communicate with various environments and sources of information, media and technology.

Soh, Arsad and Osman (2010) and Musonda (2019) have reported that 21st-century skills influence the learning outcomes. These results support the results of this study. Therefore, Bao and Koenig (2019) emphasise that future education needs to integrate 21st-century skills into the curriculum. The aim is that 21st-century learning skills can be systematically implemented and become a habit that accompanies the learning process. The findings in this study provide a conclusion that differences in 21st-century learning skills significantly influence the ability of seaweed product diversification. This happens because each student has different cognitive abilities to think critically, to communicate, to solve problems and to be creative in making processed seaweed products. In addition, grouping students with homogeneous learning skills has a more significant effect than grouping students heterogeneously. For the next implementation in the classroom, conducting experiments by placing groups of students with heterogeneous 21st-century learning skills need to be considered.

Theoretically and empirically, PjBL and PBL as learning strategies variables and 21st-century learning skills as learning conditions variables have a strong interaction effect on the ability of seaweed product diversification. Thus, it can be assumed that the effect of PjBL is moderated by differences in 21st-century learning skills. It can be said that the effect of learning strategies (PjBL and PBL) on ability of seaweed product diversification is strengthened by differences in 21st-century learning skills (4Cs). The effect of PjBL and PBL strategies on the ability of seaweed product diversification applies strongly to each group of 21st-century learning skills (4Cs). The results showed that there was an interaction pattern between learning strategies and 21st-century skill on the ability of seaweed product diversification. This means that the influence of PjBL and PBL on ability of seaweed product diversification applies strongly to each group of 21st-century learning skills (4Cs)

5. Conclusion

Based on the findings and discussion with regard to the study's purposes, it is concluded that 1) there are effects of learning strategies on students' ability of seaweed product diversification; 2) there are effects of the 21st-century learning skills on students' ability of seaweed product diversification and 3) there are effects of interaction between learning strategy and the 21st-century learning skills on students' ability of seaweed product diversification. The presence of the influence of PjBL, PBL and 21st-century learning skills on the ability of seaweed product diversification provides a compelling reason so that in vocational learning, integration of these two learning strategies is needed by paying attention to 21st-century learning skills aspects. Both learning strategies are applied from constructivist learning theory and 21st-century learning skills are the competencies for each student as a provision of life skills in the learning environment, and social environment.

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The author(s) declare no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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