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Natural Indicators of Borax and Its Utilization in the Development of Project-Based Student Worksheets to Improve Science Process Skills

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Abstract. The foodstuff course is one of the subjects that is closely related to the context of daily life. The learning model that has been applied by lecturers has not been able to encourage students to use science process skills optimally and produce real work. The teaching materials used also have not trained students' skills and independence in solving problems of daily life. Borax is a prohibited additive in foodstuffs. This study aims to develop borax indicators from natural substances and develop project-based student worksheets to improve science process skills. The development of natural indicators of borax was carried out using the true experimental design method. Extracts of natural indicators were tested for color change in a solution of pH 5, 7, 12 and on positive and negative borax food samples. The development of student worksheets is carried out using a 4D (defining, designing, developing, and disseminating), model and is only limited to the stage through expert review. LKM that has been developed are validated by experts. The data obtained were then analyzed descriptively. The results showed that (a) extracts from secang wood and turmeric could be used as natural indicators of borax and (b) expert assessment of aspects of student worksheets obtained results in the high and very high validity ranges. The results of the development of natural indicators of borax can be used in the development of teaching materials. The developed student worksheets are suitable for limited testing.
Keywords: Natural indicators of borax, project-based learning, science process skills, student worksheets

Introduction

Learning activities should be fun, challenging, inspiring, and innovative, and encourage the students to be actively involved. Learning activities must also provide space for them to develop creativity and independence based on their interests, talents, and development. One of the recommended innovative learning models in this 21st century that has shown success in achieving learning objectives is project based learning (PjBL) (Sumarni & Kadarwati, 2020). PjBL is a model that brings students into a project to solve problems related to everyday life and produce real work (Grossman et al., 2019). PjBL is contextual and student-centered. The students can get actively involved to interact and share knowledge during the learning process (Nora et al., 2021). Thus, it is hoped that they will have a strong motivation to learn because the knowledge gained is more meaningful, useful, and appropriate for solving problems in life (Widarti et al., 2020).

The learning linked to the context of daily life can activate the students to solve more. Contextual science learning provides opportunities for them to learn more effectively so that it can support the implementation and achievement (Majid & Rohaeti, 2018). PjBL which contains context will make the learning process more enjoyable and can support the students' mastery of science process skills (KPS) (Mulyanti & Lutfi, 2022). KPS is a comprehensive, systematic, and analytical skill possessed by scientists to apply scientific methods and logical thinking (Darmaji et al., 2019). It is not only about physical involvement, but also mental-intellectual aspect (Mulyanti & Lutfi, 2022).

KPS strengthens high quality science learning so that it can develop the student's potential, minds, activeness, and sense of responsibility in building facts, concepts, and knowledge (Winarti et al., 2019; Mulyanti & Lutfi, 2022). Therefore, there must be an implementation of KPS in science learning (Safaruddin et al., 2019). Success in developing KPS depends on the learning instruction model (Mulyeni et al., 2019). Creative teaching will create more opportunities for the students to acquire more science process skills. However, KPS is most suitable to be trained through activities in the laboratory. This will help increase the student's interest in science, problem solving, communication skills, compiling and testing hypotheses, observation, and data presentation (Shana & Abulibdeh, 2020). The students should be able to master KPS, but unfortunately, their mastery level is still very low (Syazali et al., 2021).

Lecturers can use media to train the students' independence. An alternative medium to involve the students actively is a PjBL worksheet (LKM). It is prepared based on PjBL steps. LKM uses projects as activities in finding knowledge (Aliman & Mutia, 2021). Many educators so far still use textbooks and they are not familiar with worksheets. Textbooks as teaching materials have some weaknesses like containing too general materials and discussion topics (Lerian et al., 2022). Therefore, they will not be independent in learning.

The foodstuff course is elective and can be taken by fourth semester students in the Science Education Study Program of Universitas Tidar. It is closely related to the context of daily life. One of which is additives in food. Additives are deliberately added to food with for improving food quality (Ariantini, 2019). Unfortunately, there are still some prohibited additives found such as borax (Kholifah & Utomo, 2018; Napitupulu & Abadi, 2018; Suseno, 2019; Sari et al., 2020). Borax is a compound made from the element boron which is commonly used as an antifungal, antiseptic and wood preservative (Septiani & Roswien, 2018). Borax is often abused by traders to increase profits. Traders add borax in the production process so that the food products they produce can last a long time. The ease of getting borax and its low price makes borax often used by food vendors (Misbah et al., 2018). Continuous consumption of foods containing borax can endanger human health and lead to cancer (Kholifah & Utomo, 2018; Nurlailia et al., 2021).

The learning model used in this course, namely the case method, has not facilitated the students to apply KPS to the fullest. The lecturers have not developed LKM to train the students' independence in learning activities. This research aims to develop indicators of borax from natural ingredients and use them in the development of project-based LKM to improve the students' KPS.

Methods

The research consists of two stages, namely the development of natural indicators of borax and the development of LKM. A natural indicator to identify borax in food is developed using a true experimental design method. The equipment is standard glassware. The materials include borax solution, HCl solution, NaOH solution, pH 5, 7 & 12, methyl red indicator, food samples, natural ingredients (white frangipani flowers, yellow frangipani flowers, red frangipani flowers, purple cabbage, secang wood, and purple cabbage), and filter paper. The food samples test uses a random sampling technique.

The development of natural borax indicators consists of some following points. Extracts of natural ingredients (white frangipani flower, yellow and red frangipani flowers, purple cabbage, and turmeric) are ground first. Meanwhile, secang wood extract comes from a maceration process by soaking it in hot water. The indicators are then tested for color changes in a solution of pH 5, 7, and 12. The color changes of natural indicators are also tested in positive and negative borax food sample extracts. An indicator showing a clear color change in positive and negative samples of borax is selected to test borax in different samples of meatballs on the market. The meatballs that show positive borax test results are then selected using a titration method.

The development of borax indicators results in the form of extracts of natural ingredients for identifying the presence of borax in food. The steps and results obtained from the development of natural indicators will become the basis for LKM development. LKM is designed based on a project-based learning syntax and contains activities that train the students' KPS.

The research uses the 4D development model which includes the stages of defining, designing, developing, and disseminating (Thiagarajan, 1974). The developed product is a project-based LKM to improve the students' KPS. The product is tested for feasibility by three experts. The data are collected through non-test techniques with validation sheet instruments. This research is only limited to the development stage with a validator review. Next, the results of the LKM validation are calculated using Aiken's V formula according to Equation 1. Table 1 presents the validity calculation results compared with some criteria.

$$V = \frac{\Sigma s}{[n(c-1)]} \qquad (1)$$

note:
s = r-lo
r = score given by validator
lo = the lowest validity score
c = the highest validity score
n = number of validators

Table 1. Validity criteria

Interval	Criteria
0.81 – 1.00	Very high
0.61 – 0.80	High
041 – 0.60	Moderate
0.21 – 0.40	Low
0.00 – 0.20	Very low

(source: Arikunto, 2010)

Results and Discussion

Development of Borax Natural Indicators

The indicators' color changes in pH 2, 7, and 12 solutions are used to determine the color change trajectory of each indicator in acidic, basic, and neutral solutions. Table 2 shows the color changes.

Table 2. Color changes of indicators in acidic, basic, and neutral solutions

Natural indicator	pH=2	pH=7	pH=12
White frangipani flower	Brown	Brown	Brown
Yellow frangipani flower	Colorless	Yellow	Yellow
Red frangipani	Brownish-yellow	Brownish-yellow	Brownish-yellow
Purple cabbage	Pink	Purple	Green
Secang wood	Yellow	Orange	Deep pink
Turmeric	Yellow	Yellow	Yellowish-brown

Table 2 shows that white and red frangipanis do not have a clear color change in acidic and basic solutions. Meanwhile, yellow frangipani, purple cabbage, secang wood, and turmeric have sharp color changes in acidic and alkaline solutions. A substance that can be used as an indicator is a weak organic acid or base which has a different color between the ionized and non-ionized forms (Chang, 2003). Natural indicators are for testing positive and negative borax food samples. The test samples include meatballs, wet noodles, and siomay. Borax and distilled water solutions will be the controls. Table 3 presents the results of the indicators' color changes in the positive and negative borax sample extracts.

Table 3. Color changes of indicators in positive and negative samples of borax

Sample	White frangipani	Yellow frangipani	Red frangipani	Purple cabbage	*Secang* wood	Turmeric
Borax solution	Brown	Yellow	Brownish-yellow	Bluish purple	Pink	Yellowish-brown
Aquades	Brown	Yellow	Brownish-yellow	Purple	Orange	Yellow
Meatball 1*	Brown	Yellow	Brownish-yellow	Bluish purple	Pink	Yellowish-brown
Meatball 2**	Brown	Yellow	Brownish-yellow	Purple	Orange	Yellow
Noodle 1*	Brown	Yellow	Brownish-yellow	Bluish purple	Pink	Yellowish-brown
Noodle 2**	Brown	Yellow	Brownish-yellow	Purple	Orange	Yellow
Siomay 1*	Brown	Yellow	Brownish-yellow	Bluish purple	Pink	Yellowish-brown
Siomay 2**	Brown	Yellow	Brownish-yellow	Purple	Orange	Yellow

* Sample contains borax; ** Sample does not contain borax

Table 3 shows that positive samples of borax will follow the trend of the color change of the borax solution. Meanwhile, the negative ones follow the trend of the color change of the distilled water. The indicators of secang wood and turmeric show clear color differences in positive and negative samples. White, yellow, and red frangipanis do not show clear color differences. Purple cabbage also does not perform a sharp color change in positive and negative borax samples, although Table 1 shows a sharp color difference in an acidic solution pH = 2 (pink) and a basic solution pH = 12 (green). This is because borax is a weak base. Borax (Mr=381.43 gram/mol) has a boron content of 11.34% and a pH ranging from 9.15 to 9.20 (Wahyuni, 2020). The color changes of the purple cabbage indicator in positive (bluish purple) and negative (purple) borax samples are difficult to distinguish by sight.

Secang wood and turmeric extracts may function as indicators of borax in food samples. Secang wood will change color to orange in negative samples of borax and pink in positive ones. The color change is following Purbaningtias et al. (2017). Secang wood extract contains a brazilin composite consisting of 3-O-methylbrazilin, brazilin, and brazilin compounds, with brazilin as the main component (de Oliveira et al., 2002). These compounds cause changes in the color of secang wood extract in different pH solutions. Meanwhile, turmeric contains the most important component, namely curcumin (50-60%). Curcumin is stable in acidic conditions, but it is not in alkaline conditions. Turmeric extract is yellow in the pH range of 1-7, and at a pH level higher than 7.5, there will be a brownish-red color change. Curcumin is degraded into furolilmetan (4-hydroxy-3-methoxynamyl-methane) and ferulic acid (4-hydroxy-3-methoxynamitic acid) in neutral and alkaline states (Stankovic, 2004).

Natural indicators from *secang* wood extract and turmeric are used to test for borax in various samples of meatballs on the market. Table 4 presents the complete test results.

Table 4. Test results for borax in various samples of meatballs on the market using natural indicators from extracts of *secang* wood and turmeric

Sample	*Secang* wood	Turmeric	Note
Meatball 1	Pink	Yellowish-brown	+
Meatball 2	Pink	Yellowish-brown	+
Meatball 3	Orange	Yellow	-
Meatball 4	Orange	Yellow	-

Table 4 shows that two of the four meatball samples contain borax. This is following the results of previous studies which found borax in meatballs sold in the market (Suntaka, 2015; Napitupulu & Abadi, 2018; Suseno, 2019; Sari et al., 2020). Borax can kill microorganisms, so it is widely used to inhibit the growth of mold and mildew in the textile industry. Also, borax works as an insecticide in the paper, glass, plastic, and leather industries (Alsuhendra, 2013). Borax has been banned as a food additive. It can accumulate in human body cells. Its harmful effects on health will not arise directly (Tubagus, 2013). However, at high levels, it can cause poisoning to death (Alsuhendra, 2013). The borax content in the meatball samples is then determined using the titration method according to equation 2.

$$Na_2B_4O_7.10H_2O_{(aq)} + 2HCl_{(aq)} \longrightarrow 2NaCl_{(aq)} + 4H_3BO_{3(aq)} + 5H_2O_{(aq)} \quad (2)$$

Table 5. Borax levels in meatball samples

Sample	Volume HCl 0,05 M (mL)				Borax level (%)
	V_1	V_2	V_3	V rata-rata	
Meatball 1	0.7	0.7	0.8	0.73	0.28
Meatball 2	1.2	1.1	1.1	1.13	0.43

Table 5 presents the borax levels in the meatball samples. The results are similar to Suseno (2019) and describe that prodecer use borax without a definite standard or dosage. This is certainly dangerous for the health of consumers.

Development of LKM

The products resulting from the development of borax indicators are used for the development of LKM in the foodstuff course. LKM is designed based on project-based learning steps and includes some activities that train science process skills. The research findings are explained based on the stages of the research model, namely define, design, and development.

Define

The first stage in product research development is "define". The Foodstuffs course is an elective for Semester IV students of the Science Education Study Program of Universitas Tidar. The basic problem in the implementation of learning for this course is that the learning steps do not train the KPS ye. There are also no worksheets that support the improvement of KPS. The implemented learning (case method) has not facilitated the students to hone their KPS. The course material developed is food additives. It is expected that the students can master the concept of additives. The expected final ability after attending this course is that they can identify harmful preservatives in food, identify natural ingredients as the indicators of borax, and determine levels of borax in food. Therefore, it is necessary to develop project-based LKM to enhance KPS.

Design

It is the designing stage of LKM based on some criteria adapted from the Ministry of National Education (2008) which includes (1) title, subject, semester, and location, (2) study guide, (3) competencies; (4) indicators; (5) supporting information, (6) work steps, and (7) assessment. The developed LKM also meets the didactic, construction, and technical requirements (Darmojo, 1992). LKM is structured based on PjBL learning steps according to The George Lucas Educational Foundation (2005), namely basic questions, preparing project designs, preparing work plans, implementing and monitoring projects, testing the results, evaluating, and reflecting. LKM also contains activities that train KPS which include basic and integrated skills based on the (American Association for the Advancement of Science, 1966).

Development

The designed LKM is then developed. The appearance of the developed LKM is presented in Figure 1.

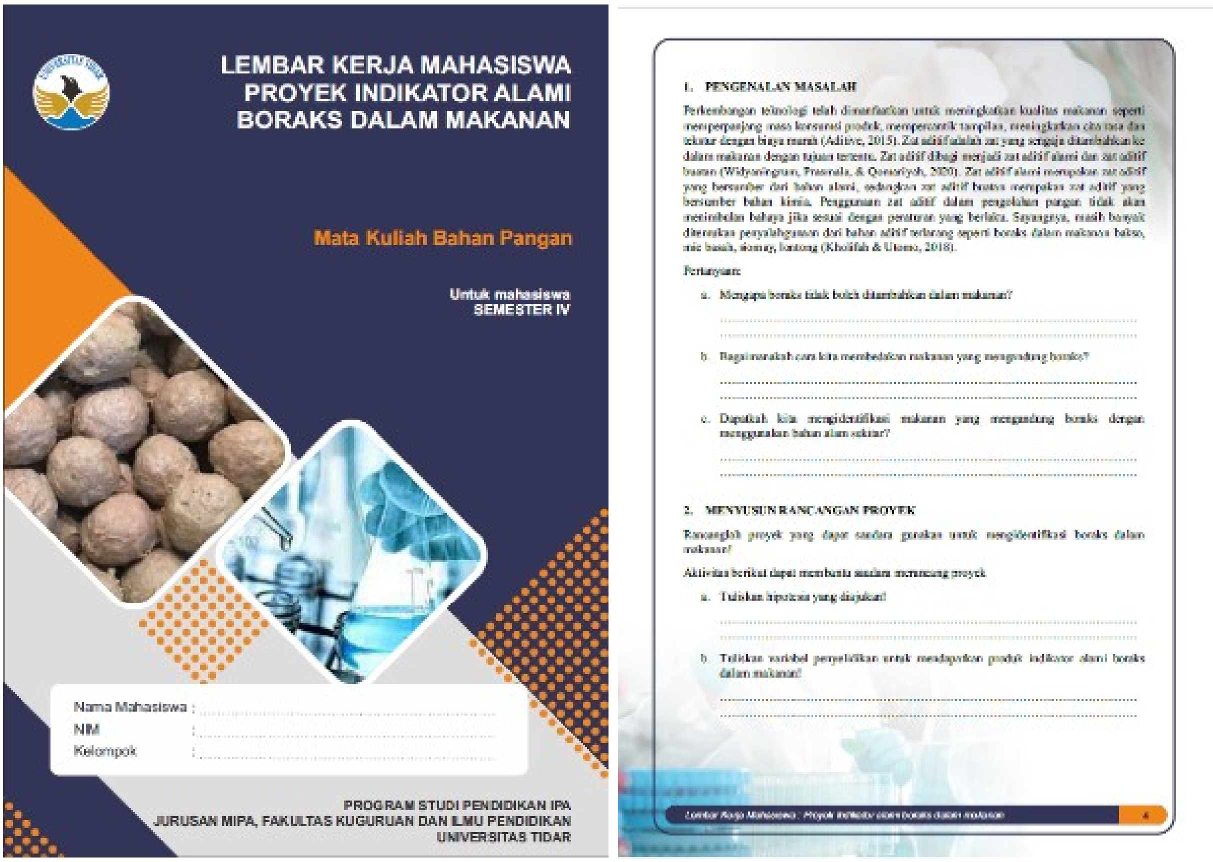

Figure 1. Visual representation of the developed LKM

The developed LKM are validated by experts and Table 6 presents the results. The LKM's assessment aspects (didactic, construction, and technical) consist of high and very high validity. The didactic aspect relates to LKM being able to facilitate all students' abilities in discovering concepts. The construction aspect relates to the clarity of the material in the LKM, the choice of words, sentence structure, and the use of LKM language. While the technical aspects concern the selection of the type and size of the font, image and appearance of the LKM. The results of expert validation have fulfilled for further testing. Worksheets as a type of teaching material function as a learning tool for educators and students (Lerian et al., 2022). The use of LKM should be able to overcome the limitations of textbooks as the most common learning source. These limitations include a general textbook discussion by presenting a lot of materials, a little enrichment of practice questions, and not yet leading students to find concepts (Lerian et al., 2022). Meanwhile, the worksheet contains activities that students must do in forming their basic skills and understanding according to indicators of learning outcomes (Susilawati et al., 2020). The suggestions from the validator are used as LKM's improvements. Table 7 displays the suggestions from validators for the LKM's improvements.

Table 6. The results of the LKM based on the borax natural indicator project

No		Valued aspect	V Aiken's	Criteria
1		Didactic		
	a	CPMK and expected final capabilities are formulated	0.92	Very high
	b	LKM is directed at efforts to realize the project	0.92	Very high
	c	LKM is directed at trying to find concepts	0.92	Very high
	d	LKPD components help develop cognitive abilities	0.83	Very high
	e	LKM activities train science process skills	0.92	Very high
2		Construction		
	a	LKM identity describes the profile of students	0.92	Very high
	b	Project completion starts from a simple to a complex stage	0.92	Very high
	c	The sentence structure used is accompanied by operational verbs whose achievement can be measured	0.75	High
	d	The use of language is following the psychological development of students	0.75	High
	e	LKM uses references that support teaching materials	0.92	Very high
	f	LKM uses effective sentences	0.75	High
3		Technical		
	a	The title of the LKM describes its contents	1	Very high
	b	Readability of writing and typeface used	0.92	Very high
	c	Tables and writings are arranged proportionally	0.92	Very high
	d	LKM appearance or layout	0.8	High

Table 7. LKM improvement based on validation results

Validation source	Before improvement	After improvement
Expert lecturer	The introduction of the problem does not include differences in foods that contain and do not contain borax	The introduction of the problem has included differences in foods that contain and do not contain borax
	Questions on problem recognition: a. Why is food mixed with borax? b. What are the dangers of borax for health?	Questions on problem recognition: a. Why can't borax be added to food? b. Deleted
	It does not include references to observation tables in concluding	It has included references to observation tables in concluding

Validation source	Before improvement	After improvement
	natural materials that can be used as borax indicators	natural materials that can be used as borax indicators
	Some sentences use the type and size of letters that are not uniform	Sentences have used the font type and font size is not uniform
	Some words have the wrong spelling	The wrong spelling of words has been fixed

Table 7 shows that there is only a slight correction from the validator. The LKM is then corrected based on the suggestions, so that the content in the LKM is more interesting and better at encouraging students to actively construct their own knowledge. This is in accordance with the statement of Anjarwati et al. (2018) that LKMs that are designed systematically and attractively are able to help students learn more actively and with focus. MFIs can be designed by containing problems in everyday life related to material concepts and their solutions can be carried out through project assignments (Sari & Wulanda, 2019). The developed LKM contains borax problem-solving activities by compiling a project. The following sections explain the activities in detail.

Basic questions

The learning starts with associating learning material with real and relevant problems (the use of borax as a food additive). The LKM contains basic questions such as (a) why can't borax be added to food? and (b) how do we distinguish foods that contain borax? These questions encourage the students to conduct an in-depth investigation of the topic.

Designing a project

Project planning is done collaboratively between the lecturers and the students. It aims to make the students a sense of ownership and responsibility for the project. Planning contains some steps to answer the fundamental questions asked before. They plan a project in the form of a natural indicator to test borax in food. Some activities in preparing the project design contained in the LKM are (a) writing research hypotheses, (b) writing research variables to obtain natural borax indicator products, (c) writing tools, materials, and work methods, and (d) compiling observation tables.

Preparing work plan

The lecturers and the students jointly arrange a series of activities in completing the project. The students write down the agreed schedule in the project implementation table listed on the LKM. Several activities in the work plan include (a) compiling a timeline and deadline for project completion, (b) encouraging the students to plan new ways of working, (c) directing the students if they develop ways of working that are not related to the project, and (d) asking the students about the selection of work methods (The George Lucas Educational Foundation, 2005)

Project implementation and monitoring

The students carry out the project according to the design and schedule that have been set. Each activity embodies the project and the progress. The results obtained are recorded at the LKM. Thus, the LKM functions to record the students' activities. Meanwhile, the lecturers are responsible for monitoring their progress in completing the project. The George Lucas Educational Foundation (2005) stated that in monitoring activities, the lecturers act as mentors and facilitators for the students.

Result testing

The results testing activities contained in the LKM consist of (a) discussing projects that have been obtained, (b) presenting the results of the discussions, and (c) writing reports in the form of scientific articles. Jeenthong, et al. (2014) stated that science learning should move towards its application in scientific work. Therefore, it is not only oriented toward remembering concepts. The George Lucas Educational Foundation (2005) explained that the results test helps the lecturers in measuring the level of standard achievement, providing feedback on student understanding and assessing the progress they have achieved, and evaluating the materials to plan further learning strategies.

Evaluation and reflection

The lecturers and the students carry out evaluations and reflections at the end of the learning process. The evaluation and reflection activities listed in the LKM include (a) explaining the advantages and disadvantages of natural materials as borax indicators, (b) drawing conclusions from the project activities that have been carried out, and (c) explaining the experience that has been gained. During the evaluation, the discussion aims to improve performance to obtain new findings as a solution to the problems posed at the beginning of learning (The George Lucas Educational Foundation, 2005). The evaluation and reflection stages should be able to culminate in a finding regarding natural ingredients used to identify borax in food. The selection of natural materials as indicators of borax must consider their advantages and disadvantages. Thus, the findings can solve the problem of how to identify borax in food.

PjBL has been known to be able to facilitate students to use KPS (Nuraini & Waluyo, 2021). To achieve KPS mastery, students need to be guided by using LKM (Rahmawati et al., 2022). The series of discovery activities contained in the LKM facilitate the students to use different KPS. Table 8 shows the KPS highlighted from LKM. LKM should be developed to encourage the student's independence in solving real problems and improving KPS. This is following Putra et al. (2015) and Citradevi et al. (2017), that worksheets can be used to improve KPS in active learning in the classroom through project activities and practicum. Besides, the use of worksheets in the learning process can streamline the learning process, and encourage, facilitate and help participants to learn actively and better (Susilawati et al., 2020). Science process skills are vital in learning science because learning will consider the process and final result (Fikriyah & Gani, 2015).

The developed LKM contains activities to train basic and integrated science process skills as shown in Table 8. The basic KPS contained are observing, measuring, concluding, predicting, classifying, communicating. While the integrated KPS includes data interpretation, formulating hypotheses, and designing experiments. Basic skills are the foundation for mastering more complex integrated skills (Bulent, 2015; Darmaji et al., 2019). Students must have basic skills first in order to be able to master integrated skills (Turiman et al., 2012). For example, students who do not master basic observing skills, these students will not get information and problems to be solved (Darmaji et al., 2019). Observation skills can encourage other skills such as inferring, predicting, and communicating (Rezba et al., 2003). Thus, if students do not fully master KPS, it will hinder their mastery of higher abilities (Darmaji et al., 2019). The weakness of the developed LKM is that it does not yet contain the skill activities to control variables and define variables operationally. Therefore, further research is expected to be able to develop LKM that facilitate students to develop all KPS.

Table 8. KPS contained in LKM

Nu	Aspect of KPS	Students' Activities
1	Observing	Observing and collecting data on the color change of natural indicators in the test sample extracts
2	Measuring	Weighing the ingredients, measure the volume of the solution
3	Concluding	a. Concluding natural ingredients that can be used as indicators of borax b. Concluding food samples containing borax
4	Predicting	Using natural indicator color change trends to determine borax-containing food samples
5	Classifying	a. Recording the observation data according to the observation table b. Classifying natural materials that can and cannot be used as indicators c. Classifying positive and negative borax food samples
6	Communicating	a. Explaining the results of the project, namely natural materials that can be used as borax indicators b. Describing empirical data on quantitative tests of borax in food c. Preparing reports on project results in the form of articles systematically
7	Data interpretation	a. Finding the trend of the color change of natural indicators in food extracts positive and negative borax b. Interpreting the HCl volume data required for titration with borax levels in food samples
8	Formulating hypotheses	Formulating a natural product investigation hypothesis that can be used as an indicator of borax
9	Designing experiments	Designing an experiment to determine natural materials that can be used as borax indicators

LKM contains activities to train KPS as shown in Table 8. By using LKM, students directly practice science process skills. Kurniawan et al. (2022) stated that students' KPS would increase if they were given the opportunity to practice these skills. Meanwhile, students' KPS is needed to build students' concepts and understanding (Farida et al., 2020). Thus the content of activities in the LKM will greatly determine the quality of learning and mastery of the competencies of students. The LKM developed has the advantage that students design projects using natural materials and materials around them. Learning by utilizing materials around and natural materials will not reduce the content of learning. Students easily get these materials and consider science close to everyday life (Mastura et al., 2017).

Conclusion

The research findings conclude that extracts of secang wood and turmeric can be natural indicators of borax contents in food. LKM is developed based on research on the development of natural indicators of borax. It is structured based on the PjBL syntax and contains activities that can train the students' KPS. Assessments by experts on the didactic, construction, and technical aspects of the LKM show high and very high validity levels. Therefore, LKM is eligible for testing to the next stage for limited trials.

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