Scientiae Educatia: Jurnal Pendidikan Sains (2018), Vol 7(2), 197-217
DOI: http://dx.doi.org/10.24235/sc.educatia.v7i2.3099
Published by Tadris IPA Biologi, IAIN Syekh Nurjati Cirebon, Indonesia. p-ISSN: 2303-1530, e-ISSN: 2527-7596

SCIENTIAE EDUCATIA: JURNAL PENDIDIKAN SAINS

journal homepage: www.syekhnurjati.ac.id/jurnal/index.php/sceducatia

www.syekhnurjati.ac.id/jurnal/index.php/sceducatia/article/view/3099

Traditional Biotechnology Content as a Media in Engaging Students with System Thinking Skills

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article info

Article history:
Received: 13 August 2018
Received in revised form: 29 December 2018
Accepted: 30 December 2018
Available online: December 2018

Keywords:
System Thinking
Traditional Biotechnology
STREAM

abstract

Traditional Biotechnology Content as a Media in Engaging Students with System Thinking Skills. A study about how to engage students with System Thinking Skills as part of 21st-century skills into Traditional Biotechnology content was conducted using Science-Technology-Religion-Engineering-Arts-Mathematics approach through one group pretest-posttest design. The study involved 43 students from a 5th semester in one University determined purposively. Data were collected through a system thinking test and interview format. After being received through instruments mentioned before, data were then processed using percentage criterion n-gain on a test and analyzed the result of student's interview. Research results show 60.47% of n-gain (moderate) with the best achievement is in the ability to explain the function of each component, while the weakest performance is in the ability to analyze the energy cycle. The result of the interview shows that the students can follow the lecture stages due to the repetitive and continuous assignment. The constraints found are in managing assignments within lecture time and less explored on religious aspects. Thus, Traditional Biotechnology content can facilitate students on system thinking skills.

1. Introduction

System Thinking Skills (STS) is one of the skills developed in the 21st century (Bybee, 2010). STS is in line with the objectives of science education including in Biology education by providing students with an understanding of the complexity of the environment around it (Boersma, Arend, & Kees, 2011; Dauer & Dauer, 2016). STS is essential to provide to students and society so that they are accustomed to making decisions in solving complex life problems (Dawidowicz, 2012; Habron, Lissy, & Laurie, 2012). To show the urgency of STS so that STS learning in various countries begins to be trained to students from the secondary to tertiary level including teachers to support sustainable development (Eilam, 2012; Habron, et al., 2012; Assaraf, Jeff, & Jaklin, 2013; Junge, Wilhelm, & Hofstetter, 2014; Raved & Yarden, 2014; Karaman, 2014; Zion & Sara, 2014; Cheng, Hung, & Liu, 2015). Biology learning in particular, has a complex study so that it is appropriate to give STS (Nursani, 2014; Dauer & Dauer, 2016; Agustina, Rustaman, Riandi, & Purwianingsih, 2017a). Notably, the provision of STS at the university level concluded that the use of various assessments could grow STS and display multiple intelligence (Habron et al. 2012) and on the topic of Animal Disease by using system maps giving students the ability to identify elements related to lecture material, but the ability of students is still at the level of synthesis, not in a higher level in the form of implementation (Cheng et al., 2015).

Meanwhile, in Indonesia, STS has not been trained and studied at the secondary and tertiary level. In the 2013 curriculum for the achievement of STS, it has not yet emerged in the learning objectives of the Middle School Science and the Biology learning objectives of the High School (Ministry of Education & Culture, 2013a; Ministry of Education & Culture, 2013b). STS is part of 21st-century skills and one of the highest level of thinking skills (Verhoeff, 2003; Bybee, 2010; Cheng et al., 2015; Agustina et al., 2017a). However, research has now begun on the profile of STS in junior high school students who are still in the low category on the topic of Life Organization Systems (Sembiring, Rustaman, & Rohman, 2017). For the college level, system thinking instruments have been developed on climate change content and students show positive responses and better understand climate change (Meilinda, Rustaman, Firman, & Tjasyono, 2017; Meilinda et al., 2018), and on other findings in the form of quality analysis argumentation and level of mastery of concepts that can describe students' STS in Human Physiology learning (Nursani, 2014). The results of the preliminary research in the lectures on Plant Physiology concluded that students' STS are still low, especially in connecting between topics and even thinking separately (fragmented) among the concepts in the subject of Plant Physiology (Agustina, et al., 2017a). Thus, STS is essential to provide to students especially as part of 21st century skills.

One of the learning approaches to provide STS to students is the approach of Science-Technology-Religion-Engineering-Arts-Mathematics (STREAM). Learning through the STREAM approach adopt the initial perspective of the Science-Technology-Engineering-Mathematics (STEM) approach that integrates aspects of technology, engineering, and mathematics which intersect one each other and remain in the circle of aspects of science (Hsu, 2014). The STEM approach has been carried out many studies both domestically and abroad (Agustina, et al., 2017b). Learning through the STEM approach can develop habits of mind, including STS (Basham & Marino, 2013). Currently, there are developments from STEM to STEAM by adding art aspects that emphasize student creativity (Oner, Nite, Capraro, & Capraro, 2016). In fact, in South Korea, science has been studied through the STEAM approach by emphasizing aspects of imagination and feeling of art to understand science (Jho, Hong, & Song, 2016). In Indonesia, learning using the STEAM approach is one way to deal with the 4.0 Industrial Revolution (Hartanto, 2018). The STREAM approach is the development of STEM and STEAM with the addition of aspects of religion and arts. In other words, the STREAM approach involves aspects of technology, religion, engineering, arts and mathematics which intersect to support the science aspect as the main component (Agustina et al., 2017b).

The addition of the religion aspect adapts to the profile of the Biology Education graduates of Sunan Gunung Djati Bandung (UIN Bandung) to produce Biology Educators, Educational Researchers and Edupreneur (Biology Education, 2015; Agustina et al., 2017b). Learning, in this case, is synergized with achieving competence in the 2013 national curriculum. In the national curriculum, there is the term core competency in the form of a spiritual aspect (Agustina et al., 2017b). Also, through strengthening the elements of religion, UIN Bandung has a paradigm of *"Wahyu Memandu Ilmu"* (developing the knowledge/science guided by the holy book/revelation). This confirms that there is no dichotomy (conflict) between the science of religion and general science. In other words, there is an effort to integrate religious science and general science (Subandi, 2010; Natsir, 2013; Agustina et al., 2018a). In addition, the profile of graduates in the form of Edupreneur conforms to the art aspects related to creativity, innovation, design in making the technology and products (Wijaya, Karmila, & Amalia, 2015; Oner, et al., 2016; Agustina, et al., 2017a). Thus, in line with the needs of the 21st century, which corresponds to the profile of Biology Education graduates and the *"Wahyu Memandu Ilmu"* paradigm, it is vital to transform STS through the STREAM approach.

This STREAM approach follows the steps of the STEM approach which begins with identifying issues that are in the environment to be resolved by problems (Bybee, 2010; Basham & Marino, 2013; Suwarma, 2014). STREAM's lecture steps as STEM emphasize the design of the engineering process and still intersect with scientific processes (Suwarma, 2014; Rosicka, 2016; Septiani, 2016; Agustina et al., 2017b). The stages in the STREAM approach are the same as STEM using the thought process (P: Pikir), design (D: Desain), create (B: Buat) and test (U: Uji) (Suwarma, 2014). The thought stage begins with identifying problems, followed by exchanging ideas between students to solve problems. The design phase by designing, constructing the product to be produced. The stage of making the product, and the test phase by testing the product if there is a failure in the testing, then redesigning and finding solutions to renovate the model (product) produced by the students (Suwarma, 2014). The STREAM approach uses a framework from The Next Generation Science Standard (NGSS) by building three dimensions in learning including scientific and engineering skills; cross-cutting concepts in studying science and engineering; and understanding of core material in studying science (Bybee, 2013; Agustina, et al., 2017b; Agustina, 2018b).

Tasks in student worksheets are needed in the STREAM approach to guide students in following the learning stages. The worksheets contain functions with the composition of technology aspects in the form of tools (containers/places) to create products; religions in the way of spiritual competencies and the *"Wahyu Memandu Ilmu"* paradigm; engineering by designing technology (tools / containers) to make products and packaging of products produced by students; arts by paying attention to the innovation and creativity of the product and packaging; and mathematics by determining the number of tools and the size of materials, composition of materials, determining the budget for production of the product (Agustina, et al., 2017b; Agustina, et al., 2018a; & Agustina, et al ., 2018b). Meanwhile, Science aspects as the main material in the form of Biotechnology content.

Biotechnology is an issue that is solved in this study. Pardo (2002) revealed that the development of science and technology in the 21st century could be related to Biotechnology (Usak, Prokop, Erdogan, & Ozel, 2009). The development of biotechnology-based industries is overgrowing throughout the world by producing products that have commercial value (Bahri, Suryawati, & Osman, 2014). The results of international studies show that there has been learning Biotechnology through the STEM approach that shows students' abilities in knowledge, perceptions, and attitudes towards Biotechnology in medium capabilities (Bahri et al., 2014). At the college level, Biotechnology lectures are based on the STEM approach through project-based molecular biology laboratory learning methods (Movahedzadeh, Patwell, Rieker, Trinidad, & Gonzalez, 2012). The results of the preliminary study indicate that teachers in secondary education in the East Bandung region are more dominant in teaching Traditional Biotechnology content with learning resources that are around the student environment. Teachers try to provide aspects of students' thinking skills, linking Biotechnology with aspects of religion and entrepreneurship, fostering an attitude of student appreciation for the science and technology of the future (Agustina et al., 2017c). Traditional Biotechnology uses the principle of fermentation technology that utilizes microorganisms to produce various products (Thieman & Palladino, 2009). Learning about Traditional Biotechnology content with the

STREAM approach has never been done by researchers. Thus, a study of Traditional Biotechnology content was carried out with the STREAM approach.

UIN Bandung is located in the city of Bandung, which is close to Gede Bage Traditional Market where it is well known for its Cibuntu production. The wholesale market can produce organic waste every day so that it can be used as materials for the manufacture of LOM (Local Microorganisms / Biofertilizers) and Compost (Agustina et al., 2017a). Meanwhile, tofu production can produce another product called “Whey,” liquid which can be used as a material for making Nata de Soya (Azhari, 2014; Misgiyarta, 2017). At present, the city of Bandung has experienced a narrowing of agricultural land in the midst of rapid population growth, urbanization and rapid urban development. The Urban Agriculture Movement (Urban Farming) is considered the solution to overcome the narrowing of agricultural land (Department of Agriculture & Food Security City of Bandung, 2017; Agustina et al., 2017b). On the results of other studies using the STREAM approach to aquaponic content in the subject of Plant Physiology showed that students experienced problems in maintaining *kale* plants in the aquaponic system in the form of snail pest attacks. This is because students feel less informed about pests controlling (plant disturbing organisms) (Agustina et al., 2018b). This encourages the importance of introducing the manufacture of biopesticides for pest control. The production of LOM, compost, Nata de Soya, and Biopesticides utilizes the principle of fermentation from microorganisms which is the scope of Traditional Biotechnology. Thus, the STREAM approach uses Traditional Biotechnology content that is in line with the issues of the Urban Agriculture Movement and Bandung Local Potential through the manufacture of LOM products, Kompos, Nata de Soya, and Biopesticides. In other words, Traditional Biotechnology as a science aspect of the main components of STREAM. Based on the introduction, it is essential to research engaging students with STS on Traditional Biotechnology content through the STREAM approach.

The study aimed to engage students with STS through the STREAM approach. Furthermore, the research question was made, namely, how is the students’ STS using the STREAM approach? And what are the obstacles for students during the learning stages through the STREAM approach?

2. Methods

2.1 Research Design

The research method used Pre Experiments with one group which is treated through STREAM approach. The design of the study is One-Group Pretest-Postest (Fraenkel & Norman, 1990). One class of treatment which before the lecture was carried out an initial test (O) and then given lecture treatment through the STREAM (X) approach and the final test (O). The limited STS description form is applied for the initial test and the final test. Figure 1 shows the research design.

O X O

Figure 1. O*ne-group pretest – postest design*

Data sources came from the fifth-semester students of Biology Education class B totaling 43 people. The sample data was taken using a purposive method. Class B students are considered more active than other classes. Students formed ten groups. Each group consists of four students and five students. Each group consisted of the top group, middle group, and lower group students.

Each group is assigned to create a mini-proposal which is guided by the worksheets task. Mini proposal making is carried out before practicum to make traditional Biotechnology content. Practical activities take place in Biology gardens. The mini-proposal contains problems in making each content, how to solve problems, basic theory, determining the need for the number of tools, the size of materials, the composition of the work methods, the design of the product/packaging for the product and packaging. Students are asked to make the drafting of production costs and linking the contents to the religion aspect. Students are given the freedom to choose tools, materials, technology design, details on how to make products, and design of product packaging.

2.2 Research Instruments

The research instruments consisted of instruments for the primary data and supporting data. The research instruments are the primary data, namely the STS problem, the worksheets task, and the interview format. The instruments were validated by seven expert lecturers from the Indonesian Education University (UPI) and UIN Bandung, among others: two Biology education experts, an expert on the STEM approach, an assessment expert, a Microbiology

Process expert, a Biotechnology expert, a Religion-expert on Microbiology, and a STS research lecturer from Sriwijaya University (Unsri).

The question instrument was tested on 19 seventh semester students and analyzed the items in the form of reliability, differentiation, correlation, and the level of difficulty of the problem using the Anates Karno To and Wibisono (2004) program. The STS problem is using General Systems and Cybernetics theory (Boersma et al., 2011). In the General System and Cybernetics theory has detailed characteristics as presented in table 1, and examples of STS question instruments are presented in table 2.

Table 1. The characteristics of STS using a general system and cybernetics theory

Components	Characteristics
1	Identifying components in a system
2	Explaining the function of each component in a system
3	Explaining the relation among each component in a system
4	Explaining the relation between the system and the other systems
5	Analyzing the cycle of energy
6	Analyzing the balance on the rate of growth of microorganisms (microbe)

Table 2. The Example of STS questions using a general system and cybernatics theories

Characteristics	Questions	Answers	Assessment Criteria	Score
Identifying components in a system	Based on your LOM practicum. Write down three main materials/ingredients to produce LOM (Local Microorganisms)!	The answer may vary based on the practicum activity conducted by the students, for example: 1. Carbohydrate source (starch): spoiled rice, washed rice water, banana stems, etc. 2. Carbohydrate source (glucose): sugar, coconut water, etc. 3. Microorganism source: rotten fruit, golden snail, etc.	• The answer meets three criteria correctly which are carbohydrate source (starch), Carbohydrate source (glucose), Microorganism source. • The answer meets one criterion correctly • Not giving answers	3 2 1 0
Explaining the relation between the system and the other systems	Nisa will produce compost. Andi recommends Nisa to produce compost using LOM (Local Microorganisms) made by Andi. How can Andi explain to Nisa on the relation between LOM and compost?	Andi explains to Nisa that LOM is a solution resulted from fermentation containing micro and macronutrients. LOM as a live media and microorganism growth. LOM is full of microorganism which can turn into vary organic materials. Compost consists of some natural materials which are ready to decompose. Hence, fertilizers need microorganism to proceed the composting. The microorganism	• The answer is correct with correct reasons • The answers are correct with incorrect reasons • Incorrect answer • Not giving answers	3 2 1 0

Characteristics	Questions	Answers	Assessment Criteria	Score
		source can be obtained from LOM. Thus, LOM is applied as a starting point of the composting process.		

The tasks of the student worksheets are readability to seventh-semester students consisting of 7 students. Based on the results of the readability test, it was further revised to use the research instrument. Worksheets tasks are adapted to the STREAM approach which is composed of aspects of Science (S), Technology (T), Religion (R), Engineering (E), Arts (A), and Mathematics (M). The composition of the STREAM aspect that composes the worksheets task is presented in Figure 2. Figure 2 shows that on average, the most significant composition on the worksheets task is 48.21% in the science aspect and the smallest composition is 4.53% in the religion aspect.

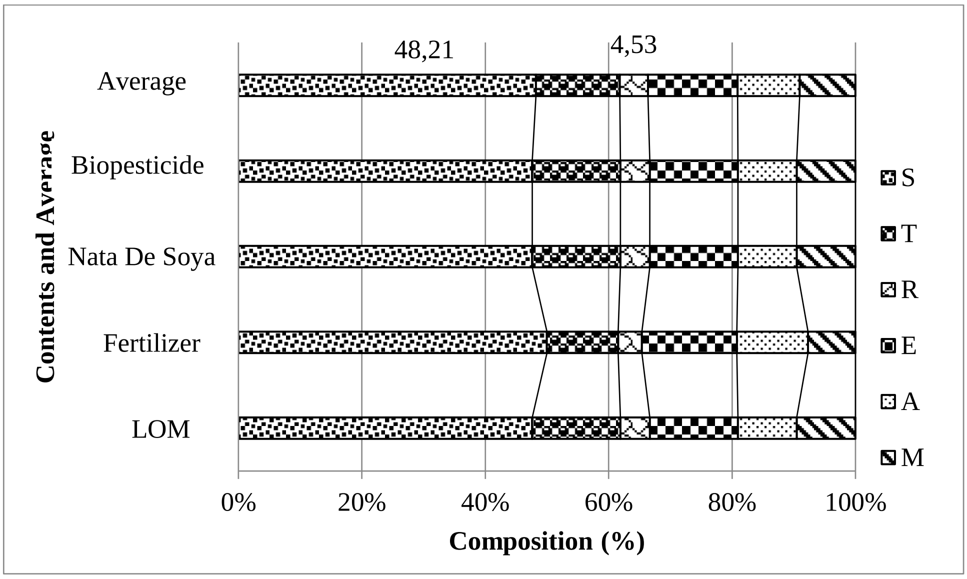

Figure 2. The composition of STREAM aspects in the student worksheets (%)

For more details on the task description of the worksheets given an example using the analysis of Cross-Cutting Concepts in the making of Nata de Soya presented in table 7, the appendix.

The format of the interview takes the form of structured questions including student constraints during lectures and suggestions from students for lectures. Interviews were conducted for three top group students, three middle group students, and three lower group students.

Research instruments as supporting data in the form of questions about the ability to think logically to strengthen discussion. Provisions for STS include logical thinking (Hidayatno, 2013). The method of collecting data with diagnostic tests in the form of TOLT (test of logical thinking) consists of 10 questions adapted from UPI. Valanides (1997) stated that TOLT aims to map students to concrete thinking criteria (concrete operational phase), transition thinking, and formal thinking (formal operational period) (Sopian, 2015). In other words, the purpose of giving TOLT is to map the ability of students' intellectual development in following the learning stages with the STREAM approach.

2.3 Learning Stages

The learning stages of the STREAM approach include: first, an initial STS test is conducted. Second, making mini-proposal based on the tasks of the worksheets. Third, the theoretical lecture activities and practicum of Traditional Biotechnology content that adapts to the Mini proposal. Fourth, technology testing in the form of containers/places that can produce products, observe products and product packaging. If there is a failure of technology and the product is not by the criteria for the success of the product, it is redesigned and analyzed to find a solution in making the product again. In the fourth stage, the stage is guided by the task of the worksheets. Fifth, a discussion of product observations is conducted. Sixth, the STS final test is performed. Seventh, interviews were conducted. Last, TOLT is conducted.

2.4 Data Analysis

For an analysis of the STS problem by comparing the increase in the initial test score and the final test score (gain). However, the initial test score shows results that are not the same for each student so that the normalized gain formula (n-gain) is used by Hake (Meltzer, 2002). Furthermore, the n-gain score is made criteria as presented in table 3. The n-gain criteria for each student are made in the form of a percentage (%) both for STS capabilities in general and for each component of STS.

$$\text{Gain} = \frac{\textbf{posttest score} - \textbf{pretest score}}{\textbf{maximal score} - \textbf{pretest score}}$$

Table 3. Criteria for gain

Average normalized gain (g)	Criteria
$g \geq 0.70$	High-g
$0.70 > g \geq 0.30$	Medium-g
$g < 0.30$	Low-g

Meanwhile, to analyze the results of interviews by describing the results of student interviews regarding obstacles during lectures and suggestions for lectures. Meanwhile, supporting data is presented in the form of TOLT analysis regarding the criteria proposed by Valanides (1997) into three criteria for intellectual development (Sopian, 2015). These criteria are presented in table 4.

Table 4. Criteria of intellectual development

TOLT Score	Criteria of intellectual development
0-1	Concrete thinking
2-3	Transition thinking
4-10	Formal thinking

3. Results and Discussion

3.1 System Thinking Skills

The results of the n-gain criteria presented in table 5 show that the achievement of most students as much as 60.47% has moderate criteria on STS in general. Meanwhile, for the results of the n-gain criteria on each STS characteristic is presented in Figure 3. The best results on the ability characteristics explain the function in each system component by 76.74% having high criteria (component 2), while the weakest ability to analyze the energy cycle characteristics (component 5). On the ability to analyze the energy cycle there are 23.36% of students have low criteria, while on the other features indicate students have a small percentage of criteria but not as large as the ability to analyze the energy cycle, for example on the characteristics of explaining the balance of microbial growth rates that only 16.28% have low criteria (component 6). The description of each STS characteristic is in table 1.

Table 5. The results of n-gain achievement of STS generally

The results of n-gain (%)	Criteria
11.63	High
60.47	Medium
27.91	Low

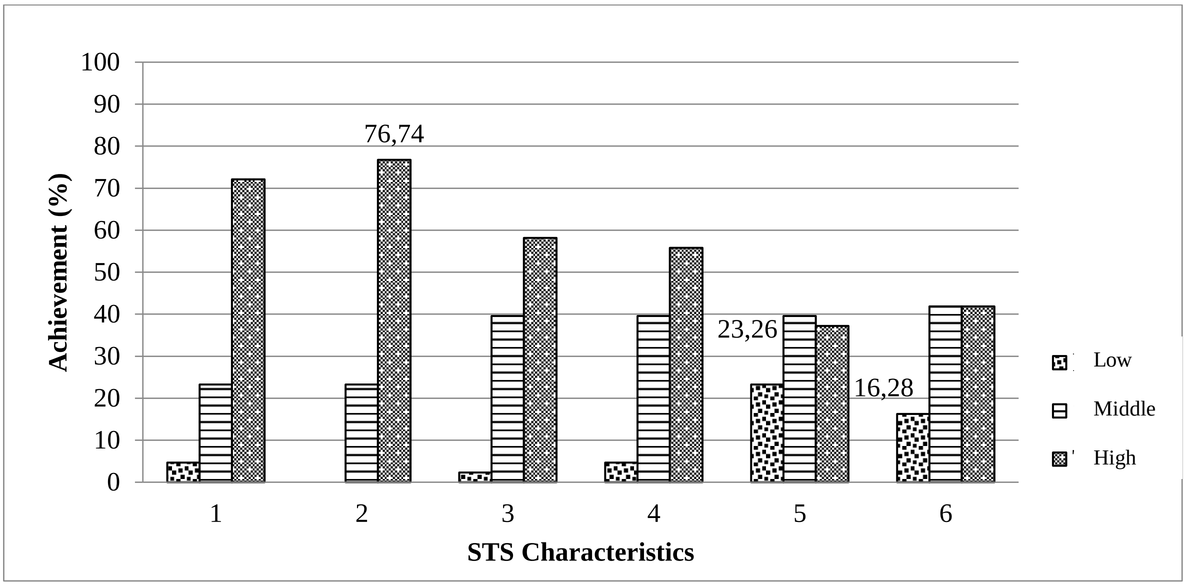

Figure 3. The result of the criteria of n-gain achievement (%) on each STS characteristics

The general theory of systems and cybernetics on LOM content, compost, Nata de Soya, and Bio-pesticides shows that each of these contents is a system. Forrester (1968) states that the system can be interpreted as a group of components that works together for a particular purpose (Nursani, 2014). In other words, the system consists of components that compose and have connections one each other. To clarify Traditional Biotechnology content as a system, examples of LOM content are presented in table 8 of the appendix. The LOM system can be connected to the Compost system because LOM can be used as a starter for making compost. Meanwhile, the TOLT results are presented in table 6.

Table 6. The result of TOLT achievement

The result of TOLT achievement (%)	Criteria of intellectual development
13.89	Concrete thinking
44.44	Transition thinking
41.67	Formal thinking

Based on the results of the study, STS generally shows that most students reach medium/moderate criteria and only 11.63% have high criteria. This condition is considered reasonable because the TOLT results show that almost half of the students are 44.44% in the transitional thinking criteria and 41.67% have entered the formal thinking criteria (table 6). Concrete thinking or concrete operational phase is the beginning of rational thinking but new students (students) can solve problems that are still concrete. Whereas formal thinking (formal operational phase) is characterized by the ability of students to think abstractly, able to express ideas, ability to predict, think scientifically, and think systemically (Toharudin, Hendrawati, & Rustaman, 2011). Most students have not entered the formal operational phase. These results indicate that students have begun to think rationally, but most students are still in the phase of transition from the concrete phase to the abstract phase so that they still need help expressing ideas, scientific thinking, and system thinking guided by the worksheet task in following the STREAM approach stages during lectures.

Meanwhile, for the details of the characteristics of STS in Figure 3 shows that the best achievement of students in the characteristics of ability explains the function of each component in the system (general system theory). On another STS theory, the system thinking hierarchy (STH) includes the analysis, synthesis and implementation sections (Assaraf et al., 2013). The ability to explain the function of each component in the system when using the STH theory is in the analysis section. On STS using STH theory shows the ability of high school students to reach the stage of analysis and synthesis (Tripto, Orit, & Miriam, 2013). Thus, students who have passed high school age show the highest achievement of analytical skills when compared to other characteristics of STS. This is also in line with the results of research by Jordan, Silver, Liu, & Gray, et al. (2013) on ecosystem topics showing the greatest increase (gain) between the initial test and the final test on the ability to identify functions when compared with other abilities.

Meanwhile, the weakest achievement of students in the characteristics of the ability to analyze the energy cycle (figure 3). Based on the STH theory that the energy cycle is part of synthesis, energy flow involves chemical reactions that are part of the metabolism. Other research results show that students have difficulty understanding the flow of energy and matter, for example in photosynthetic content which involves various chemical reactions and energy flows. Photosynthesis is part of metabolism (Hartley, Jennifer, April, & Charlene, 2012; Chabalengula, Martie, & Frackson, 2012; Larsen, Jorge, & Franz, 2015; Sordevik, Mirjamaija, & Henna, 2015). Energy cycle analysis on STS involves metabolic reactions as exemplified in table 4. Students experience difficulties in analyzing the characteristics of the energy cycle.

On the other characteristics of STS, the balance of the growth rate of microorganisms (component 6) related to the concept of homeostasis showed achievement of 16.28% with low criteria (figure 3). Westbrook & Merck (1992) state that homeostasis is a concept that is difficult to understand because the process is hidden / abstract (Assaraf, et al., 2013; Zion & Sara, 2015). Thus, the results show that there are a small number of students still having difficulty in understanding abstract concepts and based on TOLT results in table 6 shows that there are a small number of students who are in a concrete operational phase or have not been able to think abstractly.

3.2 Students' Obstacle during the Learning Instruction

Based on the results of the interview, it shows that at the beginning of the lecture on LOM content, students found difficulties in following the steps listed on the worksheets task. However, for the next meeting students are getting used to the worksheets task pattern because of repeated and continuous assignments. Students carry out practicum making activities by the Mini proposal design which is explained when class lectures are guided by the worksheets task. In practicum activities, there is a mismatch with Mini proposal for example when using disturbing plant organisms (OPT) in the bio-pesticide toxicity test. This is because almost all student groups do not carry pests so that *German caterpillars (Zopnanos Mario)* are provided for Biopesticide trials.

Students make repetitions on making LOM and Nata de Soya. Repetition of the manufacture includes aspects of engineering design. Students feel satisfied with the products produced because they are considered useful, environmentally friendly, attractive packaging and have the opportunity to be commercialized. This means that it is in line with the profile of graduates to becoming Edupreneur (Biology Education, 2015). However, specifically for content, Nata de Soya shows that students feel dissatisfied with the Nata de Soya products. The dissatisfaction was because the criteria for product success were not met as well as obstacles during the fermentation process of Nata de Soya. Students have been able to provide suggestions on product manufacturing techniques based on lecture experience. The suggestion is to reduce the amount of Traditional Biotechnology content that is considered too much.

Students feel that during the lecture they are able to activate them in discussion activities. Students are encouraged to be more creative to produce products and to add to the pleasant atmosphere of the lecture. This is in line with the results of other studies on aquaponics content that students are familiar with prescription practicum modules and demonstrations conducted by lecturers before practicum in regular lectures so that through the STREAM approach it encourages students to find other learning resources (Agustina et al., 2018b). In addition, learning through the STREAM approach and the worksheets instruments have different tasks compared to other lectures. The STREAM approach which is the development of STEM and

STEAM has the characteristics of engineering design and the scientific process. This condition is in line with the results of Movahedzadeh, et al. (2012) shows that Biotechnology lectures with the STEM approach can improve student self-confidence, performance capabilities in the laboratory, and students feel satisfied in lectures. The aim of the STEM approach, in this case, is STREAM by familiarizing STEM values with students (students) in the form of attitudes, confidence, self-resistance, and self-motivation (Zollman, 2012).

The composition of science on the task of worksheets which is more dominant reaches 48.21% compared to other aspects as presented in Figure 3 adopting the STEM perspective according to Hsu (2014) which states technology, engineering, and mathematics are in science. In other words, there is an integration of the four overlapping disciplines. Thus, in this STREAM approach aspects of technology, engineering, arts, and mathematics are in science. The condition of worksheets with tasks that have the dominant composition of science causes students to focus more on filling aspects of science and other aspects, while aspects of religion are less explored because it is only 4.53% of the composition of worksheets (figure 2). The results of other studies also showed that the compost and aquaponics content with the STREAM approach used performance assessments on practicum reports that the difference in scores between compost and aquaponics practice reports on religion aspects was only 0.46 (Agustina et al., 2018a). Thus, aspects of religion are important to note in this STREAM approach.

Also, there are students, especially the lower classes, who argue that the repeated and continuous stages of lecture make them bored with the same rhythm of the task. This is because learning through the STREAM approach, and different worksheets task forms from other worksheets encourage students to get used to expressing various ideas to solve problems in Traditional Biotechnology content. The TOLT test results show that a small percentage of students are still in the phase of concrete thinking so that difficulties in the scientific thinking process are needed in the STREAM approach. Furthermore, students feel difficulties in managing time because assignments are done outside of lecture hours. These results are in line with previous research that students feel difficulties in time management at the time of practicum (Agustina et al., 2018a). Thus, the students’ obstacles were regarding management of lecture time and lack of exploration on aspects of religion.

4. Conclusion

The findings of the study were that most students had an increase in STS with moderate criteria and some of them had high criteria. The best achievement was on the characteristics of explaining abilities on the components of the system. Meanwhile, the weakest achievement of the ability was to analyze the energy cycle. Students have been able to follow the lecture stages of the STREAM approach that are repeated in every Traditional Biotechnology content. Student constraints in managing time and exploring aspects of religion in lectures. Recommendations for further research set the lecture time and revise the student worksheets task by adding the composition of religion aspects to the STREAM approach.

Acknowledgment

Thanks to the General Directorate of Islamic Higher Education for funding this research through MORA Scholarship with Decree number 6153 in 2015.

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Appendices:

Table 7. The sample of *Crosscutting Concept* Analysis on the worksheet tasks of Nata de Soya Making

Nata de Soya Making	Engineering Process
1. Types and composition of ingredients for Nata de Soya 2. The technique of making Nata de Soya 3. Success factors in making Nata de Soya 4. Characteristics of good Nata de Soya	1. Think: identifying the problem of making Nata de Soya, looking for a solution to the problem of making Nata de Soya; 2. Design: determining tools, materials, design composition of materials, design simple incubators, determine the work steps for making Nata de Soya, and design product packaging; 3. Make: making Nata de Soya based on the design that has been made; 4. Try Out: analyzing and testing the results of making Nata de Soya according to their functions. Nata de Soya products that have been produced are by the good characteristics of Nata de Soya. If Nata de Soya product is not suitable with the characteristics, then it will be re-designed to get good results.
Cross-Cutting Concept	**Explanation**
1. Cause and effect: mechanism and explanation 2. Scale, proportion, and quantity 3. Energy and matter: Flows, Cycles, and Conservation	1. *Cause and effect*: students are guided to analyze the causes caused by making Nata de Soya, for example the sterility of tools can affect the results of Nata de Soya. 2. *Scale, proportion and quantity*: the bridge between science and mathematics in calculating the composition of the ingredients for making Nata de Soya. 3. *Energy and matter*: *Flows, Cycles and Conservation*: in the manufacture of Nata De Soya using Acetobacter xylinum which decomposes organic materials as an energy source and carbon forms a cellulose fibrillary layer. Bacterial cells will be trapped inside the cellulose fibrillary layer.

Technology	*Religion*: **Core Competence 1 (Spiritual) & A paradigm of *"Wahyu Memandu Ilmu"***
1. Using simple tools in the making Nata de Soya 2. Using a container to save Nata de Soya (simple incubators)	**a. Core Competence 1:** 1. Respecting the teachings of Islam: caring for the natural resources of God by providing the needs of microorganisms, for example Acetobacter xylinum likes acidic conditions (optimal pH 3-4), requires oxygen, and temperature 28-31^{0}C so that the ingredients for making Nata de Soya are added to acid vinegar, newspaper/paper covered pores allow oxygen to enter and be inserted into the artificial incubator to condition the temperature to stay warm. 2. Living the teachings of Islam: thanking Allah for the natural resources available in the form of ingredients (coconut water, Whey) and the presence of the microorganisms Acetobacter xylinum can be used to make Nata de Soya. 3. Practicing the teachings of Islam (implementing, implementing, fulfilling, delivering): making Nata de Soya using natural ingredients that are safe for the environment and Nata de Soya products are good for health. Natural ingredients such as Whey (first juice in making tofu), coconut water, a stew of Pengamalan sprouts as a form of worship that will get a reward from Allah. **b. The paradigm of *"Wahyu Memandu Ilmu":*** In making Nata de Soya requires ingredients such as Whey derived from tofu (tofu from soybeans), coconut water, sprouts stew, Acetobacter xylinum, sugar water, vinegar (Azhari, 2014; Misgiyarta, 2017). These materials are available in nature, especially from plants. One of the letters in the Qur'an, namely Al-Mu'minum, verses 19-21 which reads, "We have planted gardens for you, from dates and grapes. And for you, fruits are many in number, and you eat them. "And from the wood that comes out of the hill of Mount Sinai, it grows with oil and mixed spices for the people to eat. And verily in livestock is something that you should take like; We give you drink rather than what comes out of the stomach and there are also many benefits for you, thereof you also eat. ". In the translation of Al-Mu'minum verse 21 there is the phrase "... fruits and various kinds and of which you eat ..." shows us that the Most Gracious Allah has created plants for food for humans (Thalbah, Zindani, Sayid , et al., 2008). The source of Nata de Soya's ingredients comes from various plants. Nata de Soya as a healthy food source for humans. Concerning food, it must also be considered the halal as in Al-Baqarah verse 168 which is "O people! Eat from (halal) good and good things that are on the earth and do not follow the steps of Satan. The devil is a real enemy to you. " The source of Nata de Soya microorganism is Acetobacter xylinum. In general, the existence of microorganisms created by Allah is included in Yasin verse 36 (Subandi, 2010). Thus, the making of Nata de Soya is in line with Q.S. Al-Mu'minum verse 21, Al-Baqarah 168 and Yasin 36.

Engineering	*Arts*
1. Designing the composition of Nata de Soya ingredients and tools that are available in the surrounding environment 2. Designing Nata de Soya container (simple incubator) 3. Designing Nata de Soya product packaging	1. Making innovative and creative Nata de Soya (simple incubator) technology 2. Packaging Nata de Soya's attractive products while taking into account the good storage procedures of Nata de Soya
Math	
1. Calculating the tools needed 2. Calculating the composition of the ingredients used 3. Calculating the seed solution of Nata de Soya used 4. Calculating the required budget	

Table 8. Examples of STS characteristics and explanations of general systems theory and cybernetics on LOM content

Characteristics	Explanation
Identifying components in the LOM system	Components that can produce LOM, among others: 1. Source of carbohydrates (starch): stale rice, rice washing water, banana humps, and so on 2. Source of carbohydrates (glucose): sugar, coconut water, and so on 3. Sources of microorganisms: rotten fruits, golden snails, and so on
Explaining the relationship of each component in the LOM system	The functions of each component include: 1. Carbohydrate (starch) as a substrate of the fermentation process which will be changed by various microorganisms to alcohol, acid and produce energy 2. Carbohydrates (glucose) add nutrients to microorganisms during the fermentation process. Glucose undergoes the process of glycolysis into pyruvic acid. Pyruvic acid in fermentation produces ethanol, various types of carbon dioxide, water and energy (2 ATP). Some energy is used by microorganisms for growth. 3. Microorganisms as a source of microorganisms that will decompose carbohydrates
Explaining the relationship of the LOM system with the making of Compost (other systems)	Making LOM requires a source of carbohydrates (starch, glucose) and sources of microorganisms. Sources of starch carbohydrates can be obtained from rice washing water, banana humps and so on. Sources of carbohydrates are needed by microorganisms as fermentation substrates to alcohol and acids (Nisa, 2016). The source of microorganisms can come from stale rice, rotten fruits and so on. Sources of carbohydrate glucose can be obtained from sugar and coconut water. Examples of coconut water are rich in minerals, sugar, vitamins and amino acids. Microorganisms need coconut water as an addition to glucose and nutrients for fermentation.
Analyzing energy cycles	Fermentation through the process of glycolysis which breaks down glucose and the result is freeing energy in the form of 2 ATP molecules. Energy is needed by microorganisms for cell growth. Thus, it is important for microorganisms to obtain a source of carbohydrate material as a substrate for fermentation.
Analyzing the balance of the growth rate of microorganisms	In making LOM so that the rate of growth of microorganisms is optimal (exponential phase), among others: the provision of ingredients source of starch, glucose and other nutrients. Making LOM in aerobic fermentation conditions (Nisa, 2016). At the time of making LOM using a closed container to avoid the entry of oxygen which can cause the death of microorganisms.