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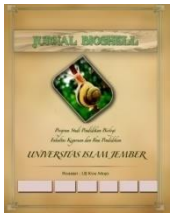

The Differences of Natural Science and Social Science Pre-service Student's Perceptions for Biotechnology

***Slamet Hariyadi, Bevo Wahono, Suratno, Jekti Prihatin, Bea Hana Siswati**
s.hariyadi.fkip@unej.ac.id
Faculty of Teacher Training and Education, University of Jember, Indonesia

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Corresponding Author*
Slamet Hariyadi,
E-mail:
s.hariyadi.fkip@unej.ac.id
No.HP/WA: 085258822616

ABSTRAK

Penelitian ini bertujuan untuk menyelidiki pentingnya menanamkan SSI (*Socioscieintific Issue*) ke dalam pembelajaran Bioteknologi berbasis STEM (*Science, Technology, Engineering, Mathematics*) dengan menganalisis persepsi siswa dalam IPA dan IPS. Hal ini dimaksudkan agar pembelajaran menjadi lebih efektif karena membantu siswa untuk mencapai pemahaman terhadap materi yang diajarkan. Penelitian ini menggunakan mix-methods dengan mengambil data kuantitatif dan kualitatif. Data kuantitatif dikumpulkan dari persentase jawaban dari 291 siswa yang telah mengisi kuis melalui survei online, sedangkan data kualitatif dikumpulkan dari pengumpulan jawaban siswa melalui wawancara tidak terstruktur. Hasil penelitian menunjukkan bahwa mahasiswa IPA lebih banyak membahas bioteknologi secara teknis dan normatif sehingga menghasilkan efek produk, sedangkan mahasiswa IPS lebih fokus pada aspek kebijakan dan risiko produk biotek. Perbedaan persepsi antara dua jurusan itulah yang mengharuskan pendekatan SSI dimasukkan ke dalam pendekatan STEM. Manfaat dari penggabungan tersebut adalah untuk peningkatan HOTS (*Higher Order Thinking Skills*) siswa yang sejalan dengan trend pembelajaran saat ini di era Revolusi Industri 4.0.

Kata kunci: SSI, Bioteknologi, Pendekatan STEM, HOTS

ABSTRACT

The study aims to investigate the importance of infusing SSI (Socioscientific Issue) into STEM (Science, Technology, Engineering, Mathematics)-based Biotechnology learning by capturing the student's perceptions in Natural Science and Social Science. This is intended to make learning more effective because it helps students comprehended the material being taught. The research applies mixed methods by capturing quantitative and qualitative data. The quantitative data are collected from the percentage of answers from 291 students who have filled out quizzes through online surveys. While qualitative data is collected from garnering students' answers through unstructured interviews. The results showed that students of Natural Science discussed biotechnology more technically and normatively resulting in product effects, while students of Social Science focused more on the policy and risk aspects of biotech products. The difference in perception between the two majors requires the SSI approach to be infused into the STEM approach. The benefits of such infusionare improved students' HOTS (Higher Order Thinking Skills), which is in line with the current learning trend of the Industrial Revolution 4.0.

Keywords: SSI, Biotechnology, STEM education, HOTS

I. INTRODUCTION

The culmination of technology in biology today is biotechnology (Zhang *et al*., 2009). Almost all the thing of life in the community can not be separated from the reach of biotechnology,such as agriculture (Altman, 1999), livestock (Hou *et al*., 2018), food (Albajes *et al*., 2013), mining (Xu *et al*., 2013), energy sources (Sandquist *et al*., 2019), health (Smith *et al*., 2002), environment (Ivanov *et al*., 2019) etc. Biotechnology has penetrated into various sectors, such as industry (Katz *et al*., 2018), information and communication (Nahurira *et al*., 2019), military (Bossi *et al*. 2006), transportation (da Silva, *et al*., 2014) , construction (Peltola, 2000) and many more. The studies also extend to dealing with the economy, law, mass media, politics, religion, etc. (Bauer & Gaskell, 2002; Suryanti *et al*., 2018).

In education, biotechnology is taught at all levels, ranging from simple to complex levels of material. The subject is taught due to the consideration that the knowledge is strongly linked to the environment of students (Styles, 2002) and its products are available in all types of stores, from simple to modern products. Students represent the generation that is expected to be able to produce profitable biotechnology products, by minimizing their negative impacts. Biotechnology requires the support of biological agents that are processed using knowledge in the field of science (Levidow & Marris, 2001; McMillan *et al*., 2000), engineering (Macer, 1994) and technology (Visser, 1998). The approach to learning biotechnology which suitible is STEM (Subekti *et al*., 2018). The learning approach does focus on the types of material related to technology and engineering. The STEM has been reported to be compatible with HOTS (Pinasa *et al*., 2017, Li *et al*., 2019, Wahono & Chang, 2019).

The essence of STEM learning is the implementation of science in the form of technology that gives an opportunity for the emergence of engineering using mathematical tool. To date, there have been debates concerning social issues in STEM teaching. The questions that develop are responses to the application of

technological and engineering results from processed products released to the society. Concerned with biotechnology, the discussion revolves around the response of biotechnology products in the community, concerning benefits and risks, opportunities for success and failure, including concerning issues of norms, law, culture and religion (Bauer & Gaskell, 2002). This requires new consideration, where in learning science - including biotechnology - one needs an additional learning approach in using STEM, namely the SSI approach. Both approaches have the potential to trigger the formation of HOTS (Diluzio & Condon, 2015; Chanthala *et al*., 2017) which is the main vision of learning this century. The formation of HOTS through a combination of SSI and STEM in learning biotechnology is important for students so that students have insight as considerations in using biotechnology products, as well as having broad insights to produce and develop biotechnology products that are safe for the community in the future. Owing to this reason, it is important to conduct research on SSI infusing into STEM in biotechnology learning by capturing students'perception from various scientific disciplines.

The role of Biotechnology in Society

Biotechnology is one of the fastest-growing areas of scientific, technical and industrial innovation of recent times, and it is also one of the most prominent topic in public discussion (Bauer & Gaskel, 2002). In Indonesia, the initial phase of biotechnology begins with producing recombinant proteins such as insulin and growth hormone. The second phase is making polyclonal antibodies, monoclonal, from hybridomas to antibody engineering. Furthermore, the third phase of cloning technology with tissue engineering technology was originally developed for the fulfillment of tissue or organ transplants. (LIPI, 2007).

Biotechnology is an effective way to meet human needs, for example, in the food sector (Thomson, 2007). Biotechnology is an effective and efficient way to meet people's needs for a product or service, which is obtained by using certain techniques (Macer, 1994) using technology (Visser, 1998). The progress of biotechnology in the future portrays the progress of a country. This mastery of high-level technology is a barometer of a country's dominance of other countries. Biotechnology can even be said as a new techno-economic paradigm (Tylecote, 2019) that can be relied upon as state gross domestic product (Arujanan, 2011; Mitze & Strotebeck, 2018), and it as a vital for society (Barciszewskia, *et al*. 2019). Its main base is nothing but technology and engineering developed from modern sciences. Thus, for countries that are unable to pursue this technology, they will be targeted by consumers for developed countries.

Biotechnology in Classroom

As one of the science materials in schools, Biotechnology is very linked to the daily lives of students (Nurlaely *et al*., 2017). The development of biotechnology is very dependent on the development of science (McMillan *et al*., 2000). The importance of biotechnology in life lies in the fact that it is one of the mandatory topics taught in science classes in Indonesia (Nursanti *et al*., 2016). School curricula have included this topic at the elementary level (Nursanti *et al*., 2016; Rota & Izquierdo, 2003) to Junior-Senior High School (Nursanti *et al*., 2016, Wells, 1994; Zeller, 1994; Dawson, 2007; Falk *et al*., 2008). This topic is interesting to discuss

(Dunham *et al*., 2002) and study by teachers and students (Kidman, 2010).

Pedagogical knowledge germane to Biotechnology is needed to balance students' understanding of Biotechnology-related contents (Suryanti *et al*., 2018). The use of innovative teaching approaches about biotechnology is an effective way to provide standards for science education. Teachers respond positively to the application of innovative learning approaches, which positively influence students' performance, increase their interest and improve classroom environment. According to Orhan & Sahin, (2018) there is a positive relationship between the teacher's innovative learning performance and educational qualifications. This is the key to success in learning biotechnology in classes.

The development of biotechnology is influenced by the development of science, technology, and the development of production techniques. Mathematical knowledge is also the basis for considering the economic benefits of technological products. So in teaching biotechnology students must understand these components. Based on researchs, many teachers use the STEM approach in teaching Biotechnology (Bahri, 2014; Subekti, *et. al*, 2018; Walker, 2018). This STEM approach integrates Science, Technology, Engineering and Mathematics, which allows students to understand integrated knowledge, and increase students' interest in science and technology (Lou *et al*., 2017). Students with STEM learning improve critical thinking skills (Chanthala *et al*., 2017; Pinasa *et al*., 2017; Ramli *et al*., 2018), innovative thinking skills (Yengin, 2014) and problem solving skills (Ponkham & Ekkapim, 2017), the overall thinking skills are included in the HOTS curriculum (Conklin, 2011).

The Interconnection Between STEM and SSI

Besides the advantages of the STEM learning approach, there are disadvantages in its implementation in the classroom, which hardly discusses the social aspects that arise from the effects of the application of science and technology. The controversial biotechnology products that arise in the community can have a dangerous impact if not well addressed by academics and scientists. The controversy referred to in Biotechnology learning relates to the interests of society, religious elements, cultural culture, customs, including legal aspects (Bauer, 2005).

According to Borgerding & Dagistan (2018), there are three types of public responses to active topics discussed in scientific forums, such as Societally-Denied Science, Less Societally-Denied Science and Societally-Accepted Science (Table 1). Denied Social Sciences is a topic that is not trusted or not recognized by community groups because of the threat of human existence and the life of the universe. The second type of response is Less Societically-Denied Science, which is scientific issues concerning human interests, but until now it has not been solved by the scientific community so that some people refute the theory. While Societally-Accepted Science is a scientific problem that is real there are products that people feel, although this also still raises the pros and cons. Examples of clonning problems and genetic modification are part of biotechnology (Bauer & Gaskell, 2002).

This indicates that problems related to biotechnology are very interesting to discuss from a social perspective. Directly or indirectly the community always

responds to all theories and products that develop from science activists, both

Table 1 *Types of Community Responses to Science Activists (Borgerding et al., 2018)*

Tipe	Description	Examples
Active science	Active science covers topics and ideas that are controversial in the science community. These ideas are actively debated and researched scientifically. With active science, controversy is within the science community itself. Active science is taught according to current events in science today where students read customized primary literature	• Firewall paradox incosmology • Stringtheory in physics
Societally-Denied Science	Topics for which the scientific community has widely achieved consensus, but some aspects of society reject the topic	• Big Bang theory & evidence • Evolution theory & evidence • Anthropogenic cause of climate change • Vaccination non-correlation with autism, evidence of herd immunity
Less Societally-Denied Science	Topics for which the scientific community has widely achieved consensus, but little aspects of society reject the topic	• HIV causes AIDs • Environmental impact of fracking
Societally-Accepted Science	Topics for which the scientific community has widely achieved consensus, and society accepted.	• Stem cell knowledge & procedures • Clonning knowledge & procedures • Genetic modification knowledge & procedurs • Alternative energy knowledge & procedurs • Environmental impact of invasive species • Effects of cigarettes on mammalian health

rejecting and accepting (Figure 1). This kind of knowledge dynamics can broaden student insight to comprehend many problems comprehensively.

Based on this reason, it is necessary to discuss biotechnology from the other side (social perspective) (Garner *et al*., 2018), one of which is through the SSI approach. How to study with this approach can build students' scientific arguments that are valid and trigger thinking skills so that they are better prepared to engage in controversial debates (Lin & Mintzes, 2010).

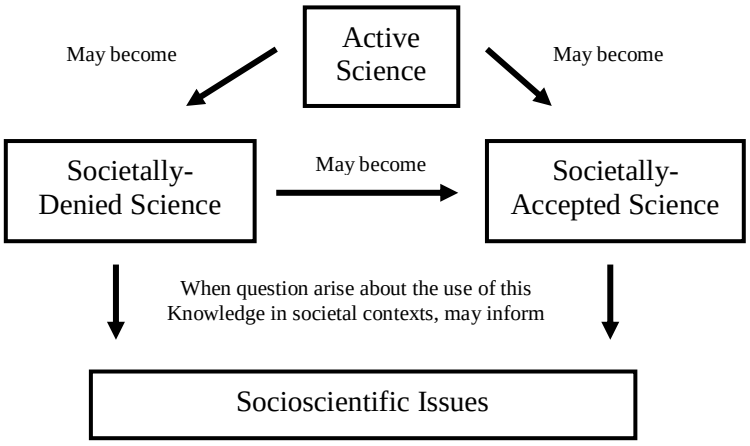

Figure 1. Relationship between active science, societally denied science, and socioscientific issues
Source: (Borgerding *et al*., 2018)

Objectives of the Study

The purpose of this study was to explore SSI's needs in a social perspective to be infused into the STEM approach.This will substantially contribute to the increase of HOTS, as a feature of 21st century learning (Greenstein, 2012). Regarding with this purpose, researchers focus on student perceptions from various scientific disciplines using biotechnology-driven topics as their study material. Besides, they also compare their open opinions so that they know the strengths and weaknesses of every emerging ideas. The results of this study can be used as the basis for the need for a combination of science and social studies formatted in the STEM-SSI approach, which will enrich the implementation of STEM learning in classroom. In this regard, there are 3 research questions that guide this research:
1) What are the opinion differences between students of Natural Science and those of Natural Science on biotechnology-related topics?
2) How do the students of Natural Science and those of Social Science address the biotechnology controversy?
3) How is the connection between SSI supporting STEM that can support HOTS ?.

METHODOLOGY

This research applies quantitative and qualitative research, known as mix methods (Bergman, 2008). The search was carried out for two months for students majoring in Natural Science and Social Science and included data collection, analysis, and integration of quantitative research using close ended question (by counting answers *yes*, *no* and *doesn't know)* and qualitative research using open ended question (giving opinions). The research approach, combining quantitative and qualitative integration,generates better understanding of a problem rather than being done separately (Sarwono, 2011).

The quantitative data includes closed information with the mechanism of data acquisition through an application on Android and inquires Biotechnology knowledge, such as the response of biotechnology products in society, benefits and risks, opportunities for success and failure, links to norms, law, culture and religion. Analysis of this type of data dealt with scores analyzed statistically descriptive. The qualitative data consisted of open information collected by researchers through interviews via Android to the same respondents. This data was a follow-up of the answers to open ended questions, which were then grouped into categories and a variety of ideas were presented in a table.

The combining analyses on both quantitative and qualitative data, the researchers were enabled to gain broader and deeper understanding and proof, to cover weaknesses that occurred when using a single approach (Sarwono, 2011). One of the most beneficial characteristics of conducting mix method research is the possibility of triangulation, namely the use of several methods (methods, data sources and researchers) to examine the same phenomenon. Triangulation provides an opportunity for researchers to identify aspects of a phenomenon more accurately by approaching it from different points using different methods and techniques. (Bergman, 2008).

Table 2 Distribution of Respondents

Category	Sub Category	Amount	Percentage (%)
Natural science	Biology	83	28,52
	Physic	71	24,40
Social science	Economy	110	37,80
	History	27	9,28
Total		291	100

Participant

The participants were 291 students from the Teacher Training and Education Faculty, University of Jember, Indonesia. The participants were involved based on departement, consisting of 154 Natural Science and 137 Social Science students. The aim of involving these students is to explore biotechnology products that are studied textually in lectures related by investigating their perceptions about these products from social spectacles.

Instrument

The questionnaire consisted of 4 close-ended items and 2 open-ended. Examples of selected questions: do you know Biotechnology? Could the biotechnology be relied upon as a solution to problems in the community? Examples of items with open questions: Could the Biotechnology products threaten the stability of biodiversity? Selected items provide answers *yes, no* and *doesn't know*. While open questions involve answers in four categories, namely the application of biotechnology, norms, policies and short answers that are not known categories.

The questionnaire aims to explore participants' general perceptions of Biotechnology products circulating in the community and their responses to these products from their respective perspectives. These questions item targets three domains. The first domain is early information on Biotechnology. The second is about predicting the effects caused. The third domain is germane to biotechnology learning opportunities.

The questions compiled have been validated by two experts namely biotechnology experts and education experts, and then realibility test. Initially there were 30 items, but then sorting was done so that the items used were 13.33%, eliminated 50.00% and grouped 36.67%. This was deemed important to ensure that the data were in accordance with the research objectives. The questions were deliberately selected, therefore leading to excluding items that differred in extreme ways, relating to basic information and further information. Basic information was taken into account because the target was broad spectrum, consisting of science (biology and physics) and social studies (economics and history) that held different perspectives on biotechnology. Further information shed light onthe depth of knowledge and insights from each respondent.

Procedure

All participants were sent questions in private and asked to respond to questionnaires online through the application on Android. Furthermore, an interesting answer was confirmed through semi-structured interviews conducted on 50 participants. From those interviewed, based on department, 25 Natural Science people (50%) and 8 social studies people (16%), while 17 (34%) Social Science people were not willing to answer. This interview aimed to explore students' perceptions in

depth to find out the logic and reasons for the answers given. There was no coercion or influence from anywhere in answering, because it was carried out during college holidays and was done personally. The questionnaire was distributed randomly, because researchers only assigned four students and did not determine the prospective respondents.

Data Analysis

The data taken in this study was the result of an online survey using an application form-based instrument Google Quiz, both for closed and open questions. In closed questions, there were three answer choices, namely *yes, no,* and *doesn't know*. Its using the descriptive quantitative method, the data were processed using Microsoft Excel to calculate the distribution and percentage. On open questions, respondents answered questions according to their opinions, the results of which wereanalyzed qualitatively and grouped into four categories, namely applications, norms, policies, short answers that are not clear. Applications relating to capacity for practical use, norms refer to the principle of right action binding upon society, policies related to methods of action selected from among alternatives to decision decisions (Webster, 2016). Then the items were coded and analyzed to be elaborated.

RESULTS

The Opinion Differences Students in Natural Science and Social Science Students on The Topics Related to Biotechnology

The difference of opinion is based on the answer choices *yes, no* and *doesn't know* of the four questions. Figure 2 shows that students of both majors differ in responding to information about biotechnology, where in question point A (Biotechnology knowledge), B (insight into biotechnology reliability), C (GMO information) and E (effect of biotechnology products) students of Natural Science mostly respond *yes*, which is different from those of Social Science. Although there is a slight difference in percentage, it shows a consistent pattern. Especially in point C, the difference is very striking. The effect of the pattern of these answers is directly proportional to the answer to point F (the opinion of the biotechnology controversy is taught in schools), where students of Natural Science are also higher than Social Science.

The opposite occurs in point E (danger of biotechnology). Social science students actually have more *no* answers than those of Natural Science. The *doesn't know* answers, the percentage of Social Science students is higher than that of students of Natural Science on all questions. The most striking difference is in point F, while the difference is the smallest at point A..

Deeper elaboration on this issue is operative by comparing students from Biology and Physics major in the Department of Science (Figure 3). The point A, B, C, and F questions, the high percentage of *yes* answers is dominated by students of Biology, while for D and E is low.

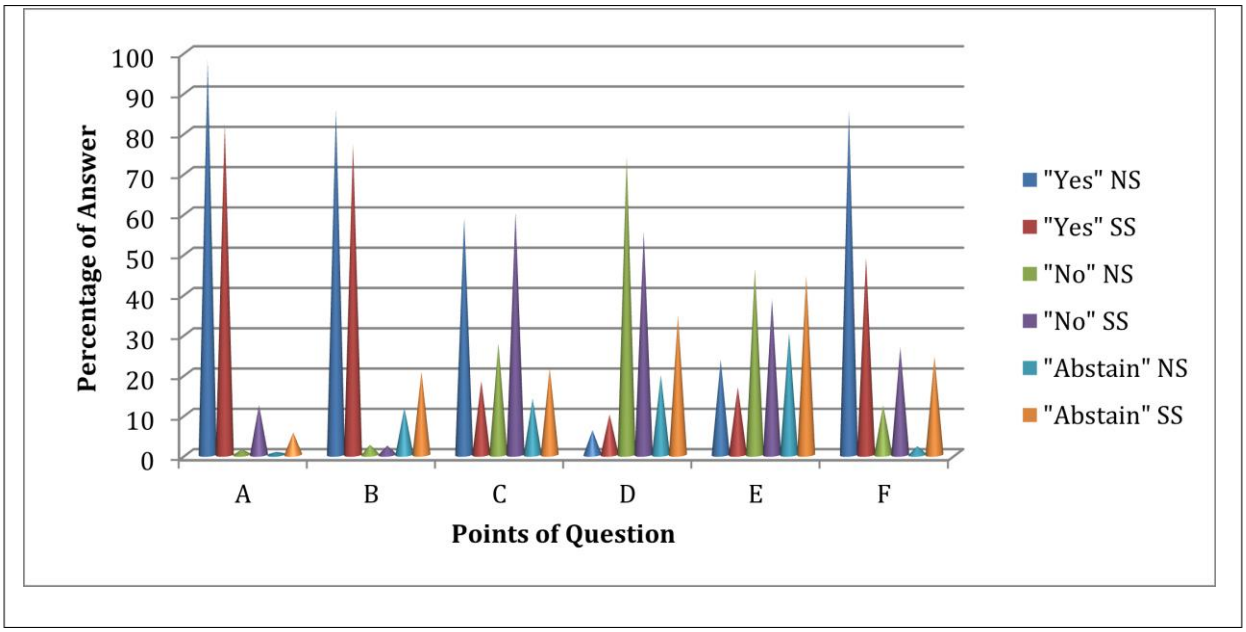

Figure 2. Distribution of data on the percentage of answers to limited students in Natural Science (NS) and Social Science (SS)

Information

A. Have you ever known information about Biotechnology?

B. Can biotechnology be relied upon as a solution to problems in society?

C. Do you know the term GMO (Genetically Modified Organism) product?

D. Are Biotechnology products harmful to society?**

E. Can Biotechnology products threaten the stability of biodiversity, cause environmental pollution, cause a reaction of the human body, and become a controversial study in the fields of law, culture, customs and religion?

F. As a prospective teacher, do you agree on topics related to controversial issues, such as genetic engineering, evolution, etc. taught in secondary schools (Junior & Senior High School)?

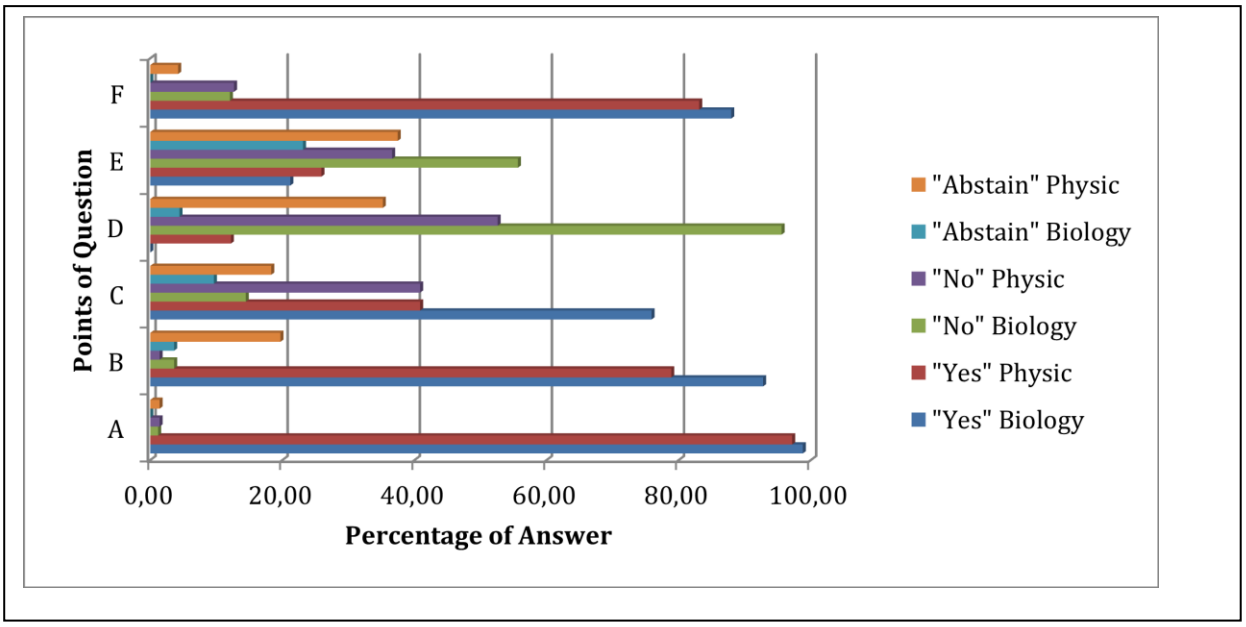

Figure 3. Comparison of student biology and physics responses

This fact is almost similar to the general percentage pattern of Natural Science students, where the points of questions A, B, C, E and F are high for the *yes* answer. So different elements of E are actually higher in student physics. This also occurs in the *doesn't know* answer, where the percentage of student Physics answers is higher in all questions. It seems that the contribution of *doesn't know* answers is dominated by students from Physics education. One interesting thing to study, for questions A and F, is that there is *no* Biology student who chooses *doesn't know*.

Students of Economics and History have different pattern that is not the same as student Biology and Physics. Questions for A, C and F are higher for Students of Economy who answer *yes*, while point questions B, D, and E are higher in students of History major. This irregularity also occurs in the *doesn't know* answer. For questions B, C, and D the percentage of answers is high for students in Economics major, while questions A, E, and F are achieved by students of History major. There is no single question whose value is zero like that of Biology students.

Differences in Perception of Natural Science and Social Science Student in The Topic of Biotechnology

In addition to limited content, respondents were also given open questions that gave students the opportunity to think according to their respective knowledge and experience capacities. Questions raised include the opportunities and benefits of biotechnology products that have been developed and disseminated to the public. Other than that relevant questions pertinent to controversial biotechnology topics are discussed in classroom learning. The answers after being grouped produce four categories, namely applications, norms, policies, short answers that are not clear.

In Table 3, it can be seen that the percentage of Natural Science and Social Science students' opinions vary. In the four categories stated, the opinions of Natural Science students dominate in two categories namely Application and Norm, while Social Science students are predominant in Policy. This shows that science students are more concerned with the technical information about biotechnology, while Social Science students are more interested in policy response.

In some perceptions, it is true that Social Science students do not provide more detailed explanations, such as perceptions about conventional biotechnology, modern biotechnology, biotechnology materials, perceptions of religious norms, and risk management. They respond to perceptions of cultural norms.

DISCUSSION

Characteristic Natural Science and Social Science in The Study of Biotechnology

As science that studies natural phenomena, Natural Science is very a dept in the study of biotechnology because it is closely related to the engineering of living things to produce certain products, which will eventually be consumed or used by other living things. Students of Natural Science as shown in in table 2 are indicated to master biotechnology issues, from their scientific side, products, effects, risks, and benefits. Based on this, it can be seen that students of Natural Science are more prominent in content issues. According to Triyanto & Handayani (2018) natural

science learning emphasizes the ability to analyze observations and experiments conducted.

Students of social studies is no less interesting, where the answers are dominant in social-community related items. They are very responsive to aspects related to the human community, because according to Triyanto & Handayani (2018) Social Science is the study of social problems in a society. They provide basic knowledge and general understanding of concepts developed to study human problems. The competencies of the two fields, there are different perspectives, but it's complementary.

Table 3 shows that natural Sciences are more concerned with technical information about biotechnology, while Social Sciences are more interested in policy responses. In the future, natural Sciences will play a role as scientists, while social sciences will play a role as policy markers. Both should not forget that people's acceptability is the most important component of the general public assessment of risk, which includes both uncertainty and negative consequences (Izquierdo, 2000). The use of biotechnology should be ethically and socially justifiable in accordance with the principle of sustainable development, safe to humans and to the environment (Izquierdo, 2000). So a policy on biotechnology was made. Thereby natural students should understand that policies.

In this regard, Social Science is significantly seen as different compared to Natural Science. The Natural Science field studies a more focused field of study on matters related to the depths, while the field of social studies is more flexible in learning things because they examine issues from a broader perspective related to society. Soo´s *et al*., (2018) argues that Social Science is more multidisciplinary than in the field of Natural Sciences, including the pattern of scientific communication. This is what distinguishes the views of students in Natural Science and Social Science studies in responding to the above questions.

Furthermore Soo´s *et al*., (2018) explain that Natural Science is usually considered to be more independent, where the majority of communication occurs internally, so that their knowledge base shows less diversity, built on a series specifically concerned with related fields. In contrast, the Social Sciences link many specializations, the flow of knowledge among broad fields, so that the intellectual background of the Social Sciences consists of a set of interrelated fields.

The respect to the Science consisting of Biology and Physics majors, students of both majors showed different characteristics (Figure 3). In principle, biotechnology emerges from the branch of biology and is included in the Biology curriculum (Bahri, 2014). The next development requires other sciences to play a role in improving the performance of biotechnology among the scientific community and the general public. On that basis, students of biology and physics major show different points of view on the answers to the questions above, but both support each other's answers.

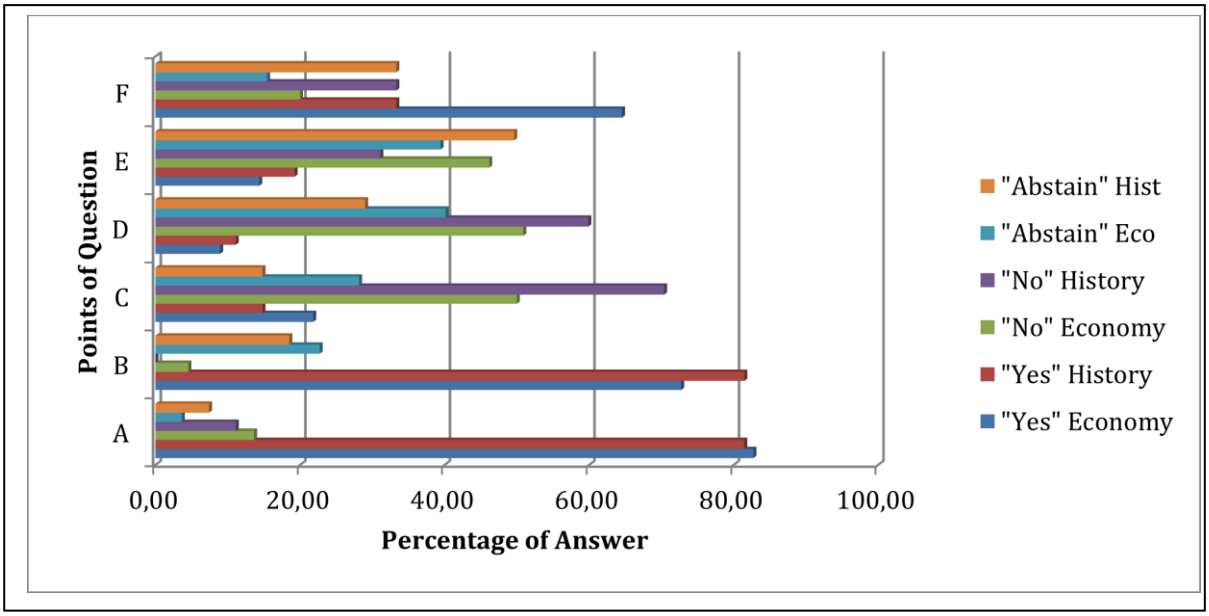

Figure 4. Comparison of student economic and historical responses

Table 3 Distribution of Open Question Data

Category	Perceptions	Percentage	
		Natural Science	Social Science
Aplication 38,46	Conventional Biotechnology	2,56	0,00
	Modern Biotechnology	2,56	0,00
	Biotechnology Materials	2,56	0,00
	Biotechnology Products	10,26	2,56
	Effects of Biotechnology	7,69	10,26
	Total	25,64	12,82
Norm 38,46	A religious norm	5,13	0,00
	Cultural norms	0,00	5,13
	Community norms	12,82	7,69
	Legals norm	5,13	2,56
	Total	23,08	15,38
Policy 17,95	Release of product	2,56	2,56
	Handling risk	2,56	0,00
	Fulfillment	2,56	7,69
	Total	7,69	10,26
Short response 5,13	Benefits	2,56	2,57
	Total	2,56	2,57
	Final Result	58,97%	41,03

Next, that is to find solutions so that each student has a thorough understanding of important aspects for the development of biotechnology. Offering science students who act as producers of biotechnology products that consider aspects of the need to produce profitable biotechnology products without negative impacts on society and the environment. Social students have agreed to biotechnology from its policy aspects. This is in accordance with their role, namely as a social review of the community, including in terms of development and dissemination of biotechnology to the public community.

There is an analogous opinion that biology is like a subdivision of *terrestrial physics* which is related to the body of living things. Thus Physics has a close relationship with biology (Keller, 2018). The difference is that Physics is more technology-oriented than is Biology (Bruun *et al*., 2018), while biology is more elaboratively descriptive in explaining natural phenomena. Technology plays a role in the development of biotechnology (Visser, 1998) thus physics students have a role as technology developers in order to support the development of biotechnology. The general public better understand predictive phenomena described in biology than physics (Johnston *et al*., 2018).

Different characteristics of social studies consisting of Economics and History. The economic perspective, the relation between biotechnology products and the economy is obvious, until the term Bioeconomics appears (Zilberman *et al*., 2015). Then it is the answers of Economics students on average which reach medium level, or do not appear to be extreme compared to those of History major. For example, students of Economics have an opinion that biotechnology can be relied upon as a solution through products that are innovative and needed by the community.This is consistent with the opinion that biotechnology is related to bioproducts, bioservices and bioprocesses (Herring *et al*., 2016) and gives birth to significant benefits, which are the foundation for the development of Bioeconomics (Twardowski, 2017). On the other hand, there are always opportunities for risk in the area of economy and law.

The caution in answering biotechnology issues causes students of Economy to choose safe answers. Evidently when answering controversial biotechnology, students of Economy are lower than those in History major. This is because their views are more on the productivity of biotechnology that can boost the country's economy. In their view, this is a good industry opportunity to increase capital gains. According to Andreev *et al*., (2019) one of the approaches to Natural Science to develop the concept of higher education in the interests of the company is by realizing innovative products in the form of economically oriented industries. These findings indicate that students have agreed to biotechnology in accordance with the field of science requested, namely true economic students in order to improve the welfare of society through the economic field. The government policies in socio-economic context have stimulated the shift from food production for subsistence or for the local community in complex farming systems to production of fewer crops and breeds for the national or global market (Visser, 1998). The economic policy making is also based on review of the controversy about biotechnology.

As for students of History, biotechnology is considered general knowledge, so the answers are more dynamic than those in Economy major. People who often judge that History only relates to name and date (Zagkotas, 2018) actually lack comprehensive understanding of the student typology of History. It turned out that in their opinion had a different perspective from students of Economy. Although students of History is a little smaller the percentage of people who understand biotechnology, but they are more convinced that biotechnology can be relied upon as a solution in society, so that no student of History who does not

believe in that condition Likewise, the percentage of those who do not understand biotechnology controversies students of History are more than students of Economy, but more students say that biotechnology has a chance of being dangerous. Perhaps due to the perspective of students of History, it is eloquentto explain historical factors and social mechanisms that contribute to conflicts that are likely to occur in society (Loogma *et al*., 2019).

Strength of The Scope of Science and Social Studies in The Study of Biotechnology

Various scientific disciplines have very different study strengths. The most frequent difference is between Natural Science and Social Science (Soo *et al*., 2018). Natural Sciences studied by Natural Science students introduced them to experimental labs so that their perceptions differed from Social Science students who discussed biotechnology in terms of its benefits and risks in society. Student Natural Science more often discusses technical processes and implications of biotechnology. This can be realized because the discussion of biotechnology is more often found in lecture materials. While in Social Sciences who have studied biotechnology at school, they are more focused on the explanation of products and biotechnology effects that they know a lot from mass media and social media. According to Nursanti *et al*., (2016), from elementary to high school (and even to college) Indonesian students were given biotechnology material, only the difference between student Natural Science was given also to senior high school while Social Science students only went to junior high school.

When observed from Natural Science students' answers, the scope is more directed to technical discussion. Problems with simple to modern biotechnology products are mentioned in their entirety. Likewise, the matter of raw materials from biotechnology products until the product forms released is also conveyed in the answer. By contrast, the social studies students mentioned more about the procedure problems of all the product series that will be made and released.

On the other hand the student Natural Science connects between changing genes with their effects on organisms, the environment and nature. The influence in question is explained in detail with examples, such as the effect of changing plants that produce transgenic organisms against the threat of destruction of predatory insects in their food webs. Meanwhile student Social Scienceis more about the effects of all products produced by Biotechnology. They do not specify them in detail, only touch from the side of the element of the actor (scientist) by reminding that something from nature that is changed by humans logically will change the other balances.

Other scopes were also discussed by the Natural Science student about the advantages of biotechnology in terms of natural revolution, product capitalization, and time efficiency. The example presented is the question of cloning which in evolution on the shortcut is in terms of the performance of the organism, then multiplied massively and marketed according to the quantity of needs in the community. Different from the Social Science student, it is more polluting the effects and risks of all actions taken, because the estuary of all

end products is to humans as well (*the man behind the gun*).

The learning approach under investigation brings these two majors together is the question of the need for biotechnology controversies delivered through learning in schools. Although according to Borgerding *et al*., (2018) as shown in Table 1, biotechnology issues are included in the Societally-Accepted Science category, but Natural Science students are still worried about the misuse of developing biotechnology products, which causes students as misguided prospective scientists to carry out innovations. Almost the same as social science students who are more afraid of the student mindset that have the opportunity to make something they want without considering the welfare of humanity.

The findings of this study become the theoretical basis for teachers or lecturers that the material on the biotechnology controversy is still a matter of getting little attention from science students, so the material needs to be emphasized more in learning. Science students also need policy materials related to biotechnology, like social studies students. So they get the full study of biotechnology material.

Integration of STEM with SSI in Biotechnology Learning

In Biotechnology learning, the pattern of integration by bringing together the content of Science, Technology, Engineering, and Mathematics (STEM) is the most appropriate learning approach (Subekti *et al*., 2018). This approach is widely used in 21st century science learning (Jang, 2016; Nurlaely *et al*., 2017; Lou *et al*., 2017), including in Indonesia (Firman, 2015; Wahono & Chang, 2019). STEM is integrated learning that involves curriculum content, teaching activities, and educational policies. The four elements of STEM, everything comes down to technical and product matters as illustrated in student science answers.

On the other hand, there are phenomena that need to be taken into account. When STEM learning took place, questions arose relating to product controversies, such as those often raised by Social Science students. This is where a debate arises that leads to the need for insight into socio-cultural knowledge. The sociocultural context is needed to overcome the weaknesses in STEM learning, in order to respond to the debate over larger global issues. The reason an argument that addresses conceptual issues related to the goals of the STEM-centric view (Zeidler *et al*., 2005) can be related to other learning approaches, such as SSI. Sociocultural perspectives framed through socioscience considerations are offered as alternative conceptualizations and surplus models for hegemonic STEM practices (Zeidler, 2014).

The SSI approach is a deliberate pedagogical tool to foster the communication skills of students in the science class. This approach can be applied to assist science students in learning aspects of policies related to biotechnology, and to facilitate students learning about biotechnology controversies. The SSI study covers Societally Denied Science and Societally Accepted Science issues including environmental pollution, global warming, depletion of natural resources (Chung *et al*., 2014), alternative energy, environmental impacts of invasive species, effects of smoking on

mammalian health, including modifications Genetic and Cloning (Borgerding & Dagistan, 2018). The last two things are part of Biotechnology. It was proven by Social Science students, although they had studied biotechnology a little while in school and obtained information from the mass media, many highlighted the policies and risks of biotechnology products.

In this regard, the important goal of science education that prepares students skilled in making decisions now and in the future (Driver, 2000). It's needs to use the SSI approach in designing students to be able to answer, make decisions and actions in relation to social dilemmas, scientific developments and technology (Ratcliffe & Grace, 2003). Moreover, biotechnology material has to do with social, ethical and economic implications in the form of risks and benefits for human life and the environment (Nurlaely *et al*., 2017).On the other hand SSI integration in science education emphasizes dialogical classroom practices that include students' views collectively with various sources of knowledge and diverse perspectives on a problem. Such classroom practice aims to empower students to participate in decision making. This can increase their independence as students and position them as participants in social discussions (Bossér & Lindahl, 2017).

Students learn to build valid scientific arguments in discussion (Active Science), concepts that can be accepted (Societally-Accepted Science) or rejected by society (Societally-Denied Science) (Figure 1) . Integration of these problems has given rise to thinking skills with knowledge about SSI. A mechanism like this, students are better able to position themselves on the problem correctly and ultimately are better prepared to engage in debates on controversial matters (Lin & Mintzes, 2010). The providing opportunities for students to discuss and debate controversial issues in the community through the SSI approach, their critical thinking skills will increase (Domenech & Márquez, 2013). The implementation of SSI as a context for learning has a significant influence on students' critical thinking skills. Controversial issues that emerge as the characteristics of SSI have encouraged students to more actively discuss and debate in order to practice critical thinking skills (Pratiwi *et al*., 2016).

Thus the characteristics and scope of students in Natural Science and Social Science can expand perceptions by fostering collaboration between disciplines. This provides an opportunity to increase the willingness to work across the boundaries of scientific disciplines, enabling actors to find solutions to problems in the most complex societies using interdisciplinary (Kirby *et al*., 2019). Combining SSI into the STEM approach will be able to improve HOTS (critical thinking skills, innovative thinking skills, problem solving skills, etc), the skill that is characteristic of 21st century learning. Thus students as the next generation can substantially contribute to the development and progress of the nation in the future.

CONCLUSION

The student's perception on biotechnology shows interesting differences, because different knowledge bases, perspectives, and scientific interests cause different perceptions to be conveyed. The results of the study indicate that the students of Natural Science are more concerned with technical issues, norms and elaboration of

controversial products, while Social Science focuses on policies and perceptions that must be addressed in biotechnology. Both complement and support each other, and agree if the controversies are conveyed by the teacher in the class. The reason causes discussions on biotechnology that have been using the STEM approach will be more appropriate if infused by the SSI approach, because in this approach two interests are included, namely in terms of natural and social perspective. This approach will trigger HOTS in solving problems comprehensively.

Limitation and Implications

The limitations in this study include the imbalance in the number of respondents between study programs and departments. This is due to its voluntary nature so that there is no obligation and there is no compulsion to answer. However, the number of respondents who were netted still met the requirements statistically and had fulfilled the representative elements of each department. Respondent selection techniques will be more effective when delivered during the learning time. The method can be considered for future times.

Other limitations are cultural and religious issues. Indonesia is known as a country with very diverse cultures (Maria, 2018) and its population is obedient in practicing religion (the majority of Moslem). In this study, religious and cultural variables have not been specifically recorded. This will be interesting to do in similar studies.

The implication of this research is that only a few of natural science who review biotechnology in terms of policy, are more dominant in social science. The ability to explain comments about the biotechnology controversy is also low, so that must be a fundamental reason for implementing STEM by instilling SSI in learning biotechnology in science students. The research results also have implications for his knowledge potential will arise when teachers carry ondeveloping STEM learning by infusing SSI, because the portion learned in the approach will also include social problems due to the application of a product from the material described. The combination of learning approaches both will trigger student HOTS, which is very good for the final learning outcomes. Other implications for policy makers can consider the SSI approach to other subjects, especially those that use the STEM approach. Students will be encouraged to uncover a real phenomenon in the community they usually experience, they see it everyday, then it can be linked to the material being taught. It is this skill that connects concepts and facts that trigger high-level skills, because students play memories in their brains to be compared, confronted, converted, to be conclusions into a more mature and comprehensive concept.

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References

Albajes., R., Cantero-Martínez. C., Capell, T., Christou, P., Farre, A., Galceran, J., López-Gatius, F., Marin, S., Martín-Belloso, O., Motilva, Ma.-J., C. Nogareda., J. Peman., J. Puy., J. Recasens., I. Romagosa., Ma.-P. Romero., Sanchis, V., Savin, R., Slafer, G. A., Soliva-Fortuny R., Viñas, I., & Voltas, J. (2013). Building bridges: an integrated strategy for sustainable food production throughout the value chain. *Molecular Breeding*. *32*(4), 743-770. Doi: 10.1007/s11032-013-9915-z

Altman, A. (1999). Plant biotechnolgy in the 21st century: the challenges ahead. *Plant Biotechnology*. *2*(2), 1-2. Doi:10.4067/S0717-34581999000200001

Andreev, A.V., Burlov, V.G., Gomazov, F.A., & Penner, Y.A. (2019). Improving the system of higher education for enterprises of industrial and economic complex. *Proceedings of 2018 17th Russian Scientific and Practical Conference on Planning and Teaching Engineering Staff for the Industrial and Economic Complex of the Region, PTES 2018*, *7* January 2019, *8604230*, 86-88.

Arujanan, M., & Baharuddin, A. (2011). Biotechnology Awareness: From the Ivory Towers to the Masses. Chapter 8. *In Communication Challenges and Convergence in Crop Biotechnology*. Navaro, M.J., & Hautea, R.A (Ed). International Service for the Acquisition of Agri-biotech Applications (ISAAA): Ithaca, New York and SEAMEO Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA): Los Baños, Philippines.

Bahri, N.M. (2014). Students' Biotechnology Literacy: The Pillars of STEM Education in Malaysia. *Eurasia Journal of Mathematics, Science & Technology Education.10*(3), 195-207. Retrieved from https://eric.ed.gov/?id=EJ1032676

Barciszewskia, J., Ciemerych, M.A., & Twardowski, T. (2019). Novel insights and innovations in biotechnology towards improved qualityof life. *New Biotechnology. 49*, 58–65. Doi: 10.1016/j.nbt.2018.09.001

Bauer, M.W & Gaskell, G. (2002). *Biotechnology, the making of a global controversy*. London: Cambridge University Press.

Bauer, M.W. (2005). Public perceptions and mass media in the biotechnology controversy. *International Journal of Public Opinion Research*. *17*(1), 5-22. Doi: 10.1093/ijpor/edh054

Bergman, M.M (Ed). 2008. *Advances in Mixed Methods Research*. London: SAGE Publication Ltd. ISBN: 978-1-4129-1.

Borgerding, L. A., & Dagistan, M. (2018). Preservice science teachers' concerns and approaches for teaching socioscientific and controversial issues. *Journal of Science Teacher Education. 29*(4), 1-24. Doi: 10.1080/1046560x.2018.1440860

Bossér, U., & Lindahl, M. (2017). Students' Positioning in the Classroom: a Study of Teacher-Student Interactions in a Socioscientific Issue Context . *Res Sci Educ*. *49*(2), 371–390. Doi: 10.1007/s11165-017-9627-1

Bossi, P., Garin, D., Guihot, A. Gay, F., Crance, M., Debord, T., Autran, B., & Bricaire, F. (2006). Biological weapons. *Cellular and Molecular Life Sciences CMLS. 63*(19-20), 2196-2212. Doi: 10.1007/s00018-006-6308-z

Bruun, M., Willoughby, S., & Smith, J.L. (2018). Identifying the stereotypical who, what, and why of physics and biology. *Physical Review Physics Education Research. 14*, 1-16, 020125. Doi: 10.1103/PhysRevPhysEducRes.14.020125

Chanthala, C., Santiboon, T., & Ponkham, K. (2017). Instructional designing the STEM education model for fostering creative thinking abilities in physics laboratory environment classes. *AIP Conference Proceedings*. Vol.1923, 5 January 2018. Article number 030010. Doi: 10.1063/1.5019501

Chung, Y., Yoo, J., Kim, S.-W., Lee, H., & Zeidler, D.L. (2014). Enhancing students' communication skills in the science classroom through socioscientific issues. *International Journal of Science and Mathematics Education. 14*(1), 1–27. Doi: 10.1007/s10763-014-9557-6

Conklin, W. (2011). Higher-Order Thinking Skills to Develop 21st Century Learners. Canada: Shell Education Publisher. ISBN13: 9781425808228.

Da Silva, T.L., Gouveia, L. & Reis, A. (2014). Integrated microbial processes for biofuels and high value-added products: the way to improve the cost effectiveness of biofuel production. *Applied Microbiology and Biotechnology*. *98*(3), 1043-1053. Doi: 10.1007/s00253-013-5389-5

Dawson, V. (2007). An exploration of high school (12-17 years old) students' understanding of, and attitudes toward biotechnology processes. *Res Sci Educ*. *37*, 59-73. Retrieved from https://link.springer.com/article/10.1007/s11165-006-9016-7

Diluzio, R., & Congdon, C.B. (2015). Infusing the creative-thinking process into undergraduate stem education: an overview. *5th IEEE Integrated STEM Conference*. 978-1-4799-1829-4/15 (2015): 52-57. Doi: 10.1109/ISECon.2015.7119945

Domnech, A.M. & Mrquez, C. (2013). Promoting Students Critical Thinking through the Design of Scientific Researches Related to a SSI: The Case of ADHD. ESERA Conference Proceding.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education. 84*(3), 287–312. Doi: 10.1002/(SICI)1098-237X(200005)84:3<287::AIDSCE1>3.0.CO;2-A.

Dunham, T., Wells, J., & White, K. (2002). Biotechnology education: a multiple instructional strategies approach. *Journal of Technology Education*. *14*(1), 65-81. Retrieved from https://scholar.lib.vt.edu/ejournals/JTE/v14n1/pdf/dunham.pdf

Falk, H., Brill, G., & Yarden, A. (2008). Teaching a biotechnology curriculum based on adapted primary literature. *International Journal of Science Education. 30*(14), 1841-1866. Doi: 10.1080/09500690701579553

Firman, H. (2015). Pendidikan Sains Berbasis STEM: Konsep, Pengembangan, dan Peranan Riset

Pascasarjana. *Seminar Nasional Pendidikan IPA dan PKLH* (Bogor: Pendidikan IPA Program Pascasarjana Universitas Pakuan)

Garner, P.W., Gabitova, N., Gupta, A. Wood, T. (2018). Innovations in science education: infusing social emotional principles into early STEM learning. *Cultural Studies of Science Education*. *13*(4), 889-903. Doi:10.1007/s11422-017-9826-0.

Greenstein, L. 2012. *Assessing 21st Century Skills: A Guide to Evaluating Mastery and Authentic Learning*. USA: Corwin Pubh.

Herring, R., &Paarlberg, R. (2016). The political ecobony of biotechnology. *Annual Review of Resource Economics*. *8*(1), 397-416. Doi: 10.1146/annurev-resource-100815-095506

Hou, Z., An, L., Han, J., Yuan, Y., Chen, D., & Tian, J. (2018). Revolution livestock breeding in the future: an animal embryo-stem cell breeding system in a dish. *Journal of Animal Science and Biotechnology*. *9*, 9. Doi: 10.1186/s40104-018-0304-7

Ivanov, V., Stabnikov, V., Stabnikova, O., Kawasaki, S. (2019). Environment safety and biosafety in construcion biotechnology. World Journal of Microbiology and Biotechnology. *35*, 26. Doi:10.1007/s11274-019-2598-9

Izquierdo, J. 2000. Biotechnology can help crop production to feed an increasing world population-positive and negative aspects need to be balanced: a perspective from FAO. Elsevier Science Publishers. 13-26 ref.17. Retrieved from: http://www.fao.org/tempref/GI/Reserved/FTP_FaoRlc/old/redes/redbio/cuba.pdf

Jang. H. (2016). Identifying 21st Century STEM Competencies Using Workplace Data. *Journal of Science Education and Technology*. *25*(2), 284-301. Doi: org/10.1007/s10956-015-9593-1

Johnston, A.M., Sheskin, M., Johnson, S.G.B., & Keil, F.C. (2017). Preference for explanation generality develop early in biology but not physics. *Child Development*. *89*(4), 1110-1119. Doi: 10.1111/cdev.12804

Katz, L., Chen, Y.Y., Gonzalez, R., Peterson, T.C., Zao, H., & Baltz, R.H. (2018). Synthetic biology advance and application in the biotechnology industry: a perspective. *Journal of Industrial Microbiololgy & Biotechnology*. *45*(7), 449-461. Doi: 10.1007/s10295-018-2056-y

Keller, E.F. (2018). Physics in biology-has d'arcy Thompson been vindicated?. *Springer Science+Business Media, LLC, part of Springer Nature. 40*(4), 33-38. Doi: 10.1007/s00283-018-9801-y

Kidman, G. (2010). What is an 'interesting curriculum' for biotechnology education? Students and teachers opposing views.*Res Sci Educ 40*, 353-373. Doi: 10.1007/s11165-009-9125-1

Kirby C. K., Jaimes P., Lorenz-Reaves AR, & Libarkin JC. (2019). Development of a measure to evaluate competence perceptions of natural and Social Science. *PLoS ONE 14*(1), 1-15. Doi.org/10.1371/journal.pone.0209311

Levidow, L. & Marris, C. 2001. Science and governance in Europe: Lessons from the case of agricultural biotechnology. *Science and Public*

Policy. 28(5):345–360. https://doi.org/10.3152/147154301781781345

Li, Y., Schoenfeld, A.H., diSessa, A.A. Graesser, A.C., Benson, L.S., English, L.D., & Duschi, R.A. (2019). On thinking and STEM education.*Journal for STEM Education Research*. *2*(1), 1-13. Doi: 10.1007/s41979-019-00014-x

Lin, S-S., & Mintzes, J.J. (2010). Learning argumentation skills through instruction in socioscientific issues: the effect of ability level. *International Journal of Science and Mathematics Education*. *8*(6), 993–1017. Doi: 10.1007/s10763-010-9215-6

LIPI. 2007. Memotret Potensi Bioteknologi di Indonesia : Data dan informasi bioteknologi di Indonesia masih tercecer dan tidak terstruktur. Indonesian Institute of Sciences Bulletin. Retrieved from http://lipi.go.id/berita/memotret-potensi-bioteknologi-di-indonesia-:-data-dan-informasi-bioteknologi-di-indonesia-masih-tercecer-dan-tidak-terstruktur./1530

Loogma, K., Umarik, M., Sirk, M., & Liivik, R. (2019). How history matters: the emergence and persistence of structural conflict between academic and vocational education: the case of post-soviet estonia. *Journal of Educational Change*. *20*, 105–135. Doi: 10.1007/s10833-018-09336-w L

Lou, S.J., Chou, Y.C., Shih, R.C., & Cung, C.C. (2017). A study of creativity in C_aC_2 steamship-derived STEM project-based learning. *Eurasia Journal of Mathematics Science and Technology Education*. *13*(6), 2387–2404. Doi: 10.12973/eurasia.2017.01231a

Macer, D.R. 1994. Perception of risks and benefits of in vitro fertilization, genetic engineering and biotechnology. *Social science & medicine*. 38(1):23-33. https://doi.org/10.1016/0277-9536(94)90296-8

Maria. (2018). Local wisdom of indigenous society in managing their customary land: a comparative study on tribes in Indonesia. *E3S Web of Conferences*. *52*, 00023. Doi: 10.1051/e3sconf/20185200023 CSSPO 2018

McMillan, G.S., Narin, F., & Deeds, D.L. 2000. An analysis of the critical role of public science in innovation: the case of biotechnology. *Science Direct*. 29(1):1-8. https://doi.org/10.1016/S0048-7333(99)00030-X

Mitze, T., & Strotebeck, F. (2018). Modeling interregional research collaborations in German biotechnology using industry directory data. *Data in Brief*. *22*, 169-180. Doi: 10.1016/j.dib.2018.11.145

Nahurira, R., Wang, J., Yan, Y. Jia, Y., Fan, S., Khokhar, I., & Eltoukhy, A. (2019). In silico genome analysis reveal the metabolic versality and biotechnology potential of a halotorelant phythalic acid esters degrading Gordoniaalkanivoransstrain YC-RL2. *AMB Express*. *9*(1), 21. Doi: 10.1186/s13568-019-0733-5

Nurlaely, N., Permanasari, A., & Riandi, R. (2017). Student's STEM Literacy in Biotechnology Learning at Junior High School. IOP Conf. Series: *Journal of Physics*: Conf. *895*, 12155. Doi: 10.1088/1742-6596/895/1/012155

Nursanti, T.E., Umniyatie, S., & Yulianti, E. (2016). Analisis kesinambungan konsep bioteknologi dalam buku pelajaran sains/biologi (Analysis of sustainability of biotechnology concepts on science / biology textbooks). *Jurnal Pendidikan Biologi Universitas Negeri Yogyakarta. 5*(1), 1-7. Retrieved from journal.student.uny.ac.id/ojs/index.php/pbio/issue/view/676

Orhan, T.Y., & Sahin, N. (2018). The Impact of Innovative Teaching Approaches on Biotechnology Knowledge and Laboratory Experiences of Science Teachers. *Educ. Sci. 8*(4), 213. Doi: 10.3390/educsci8040213

Peltola, J., Juhanoja, J. & Salkinoja-Salonen, M.S. (2000). Biodegradability and waste behavior of industrial wood-based construcion materials. *Journal of Industrial Microbiology and Biotechnology*. *24*(3), 210-218. Doi: 10.1038/sj.jim.2900808

Pinasa, S., Siripun K., & Yuenyong,C. (2017). Developing design-based STEM education learning activities to enhance students' creative thinking. *AIP Conference Proceedings*. *1923*, (030076). Doi:10.1063/1.5019567

Pratiwi, Y.N., Rahayu, S., & Fajaroh, F. (2016). Socioscientific issues (SSI) in reaction rates topic and its effect on the critical thinking skills of high school students. *Jurnal Pendidikan IPA*. *5*(2), 164-170. Doi: 10.15294/jpii.v5i2.7676

Ponkham, S.P., & Ekkapim, S. (2017). The results of STEM education methods for enhancing critical thinking and problem solving skill in physics the 10th grade level. 5th International Conference for Science Educators and Teachers, ISET 2017, 6 June 2017 at Phuket Thailand. Code 133477. *AIP Conference Proceedings*. *1923*(030045). Doi: 10.1063/1.5019536.

Ramli, A.A., Ibrahim, N.H., Yusof, F.M., & Surif, J. (2018). Critical thinking from STEM education and Al-Quran perspectives. *Journal of Engineering Science and Technology*. *13*, 35-41. Retrieved from http://jestec.taylors.edu.my/i-Cite%202018/i-Cite_05.pdf

Ratcliffe, M., & Grace, M. (2003). *Science education for citizenship: teaching socio-scientific issues.* Maidenhead; Philadelphia: Open University Press

Rota, G., & Izquierdo, J. (2003). "Comic" as a tool for teaching biotechnology in primary schools. *Electronic Journal of Biotechnology*. *6*(2), 85-89. ISSN. 0717-3458.

Sandquist, J., Tschentscher, R. & Del Alamo Serrano, G. (2019). Hydrothermal liquefaction of organic resources in biotechnology: how does it work and what can be achieved?. *Applied Microbiology Biotechnology.103*(2), 673-684. Doi:10.1007/s00253-018-9507-2

Sarwono, J. 2011. *Mixed Methods, Cara Menggabung Riset Kuantitatif dan Riset Kualitatif Secara Benar*. Jakarta: PT. Elex Media Komputindo. ISBN: 978-602-00-0598-0

Smith, J.E., Rowan, N.J. & Sullivan, R. (2002). Medical mushrooms: a rapidly developting area of biotechnology for cancer therapy and other bioactivities. *Biotechnology Letters*. *24*(22), 1839-1845. Doi: 10.1023/A:1020994628109

Soo´s, S., Vida, S., & Schubert, A. (2018). Long-term trends in the multidisciplinarity of some typical

natural and Social Sciences, and its implications on the SSH versus STM distinction. *Scientometrics . 114*, 795–822. Doi:10.1007/s11192-017-2589-2

Styles, M.L.B. (2002). Using education as a public relations tool for biotechnology. *Plant Cell, Tissue and Organ Culture*. *70*(1), 23-26. Doi:10.1023/ A:1016044806450

Subekti, H., Purnomo, A.R., Ibrohim., & Suwono, H. (2018). Comparison of Student Achievement in Agricultural Biotechnology-STEM Integrated Using Research Based Learning. IOP Conf. Series: *Journal of Physics*: Conf. *1108,* 012100. Doi: 10.1088/1742-6596/1108/1/012100

Suryanti, E., Fitriani, A., Redjeki, S, & Riandi, R. (2018). Identification of Conceptual Understanding in Biotechnology Learning.*Materials Science and Engineering.* IOP Conf. *335*, 012093. Doi: 10.1088/1757-899X/335/1/012093.

Thomson, J.A. 2007. The role of biotechnology for agricultural sustainability in Africa. *The Royal Society Publishing*. 363(1492). https://doi.org/10.1098/rstb.2007.2191

Triyanto & Handayani, R.D. (2018). Comparing learning motivation and learning style between Natural Science and Social Science students in higher education. *International Journal of Innovation and Learning*. 23(3):304-317. Doi: 10.1504/IJIL.2018.091089

Twardowski, T. (2017). Executive summary of the report of the committee of biotechnology of the polish academy of sciences Bioeconomy, biotechnology and new genetic engineering techniques. Modern biotechnology-based bioeconomy in a circular economy. *Biotechnologia*. *98*(4), 333-335. Doi:10.5114/bta.2017.73372

Tylecote, A. (2019). Biotechnology as a new techno-economic paradigm that will help drive the world economy and mitigate climate change. *Research Policy*. *48*, 858–868. Doi: 10.1016/j.respol.2018.10.001.

Visser, B. 1998. Effects of Biotechnology on Agro-biodiversity. *Biotechnology and Development Monitor*. No. 35, p. 2-7. Retrieved from: http://www.biotech-monitor.nl/3502.htm

Wahono, B., & Chang, C.Y. (2019). Assessing teacher's attitude, knowledge, and application (AKA) on STEM: an effort to foster the sustainable development of STEM education. *Sustainability. 11*, 950. Doi: 10.3390/su11040950

Walker, L. (2018). STEM Education: An Important Component of the Industrial Biotechnology Innovation Nexus. *Industrial Biotechnology. 14*(5), 235–235. Doi: 10.1089/ind.2018.29150.lpw

Webster, M. (2016). *The Merriam-Webster Dictionary*. USA: Merriam-Webster, Incorporated. ISBN: 087779295X, 9780877792956. Retrieved from https://www.merriam-webster.com/dictionary/dictionary

Wells, J.G. (1994). Establishing a taxonometric structure for the study of biotechnology in secondary school technology education. *Journal of Technology Education. 6*(1), 58-75. Retrieved from https://eric.ed.gov/?id=EJ517388

Xu, K., Tang, Y., Ren, C. Zao, K., Wang, W, & Sun, Y. (2013). Activity, distribution, and abundance of methane-oxidizing bacteria in the

near surface soil of onshore oil and gas fields. *Applied Microbiology and Biotechnology*. *97*(17), 7909-7918. Doi: 10.1007/s00253-012-4500-7

Yengin, I. (2014). Designing mobile application for STEM: building individual interest and suporting creative and innovative thinking skills. 22nd International Conference on Computers in Education, ICCE 2014; Nara; Japan; 30 November 2014 through 4 December 2014; Code 110502, Pages 187-194. Workshop Proceedings of the 22nd International Conference on Computers in Education, ICCE 2014.

Zagkotas, V. (2018). Are comic books appropriate for teaching History? Three suggestions for Greek Primary Education. *Education 3*(13), 1–8. Doi: 10.1080/03004279.2018.1452955

Zeidler, D.L., Sadler, T.D., Simmons, M.L., & Howes, E. V. (2005). Beyond STS: A research-based framework for socioscientific issues education. *Science Education. 89*, 357–377. Doi: 10.1002/sce. 20048

Zeidler, D.L. (2014). STEM education: A deficit framework for the twenty first century? A sociocultural socioscientific response. *Cultural Studies of Science Education. 11*(1), 11–26. Doi: 10.1007/s11422-014-9578-z.

Zeller, M.F. (1994). Biotechnology in the High School Biology Curriculum: The Future Is Here!. *The American Biology Teacher, 56*(8), 460–464. Doi: 10.2307/4449889

Zhang, W., Bai F.W., & Zhong, J.J. (2009). 13th International Biotechnology Symposium and Exhibition: Biotechnology for the Sustainability of Human Society. *Biotechnology Letters. 31*(9), 1313–1314. Doi: 10.1007/s10529-009-0021-6

Zilberman, D., Graff, G., Hochman, G., & Kaplan, S. (2015). The political economy of biotechnology.*German Journal of Agricultural Economics. 64*(4), 212-223. Retrieved from https://www.researchgate.net/publication/288006243_The_political_economy_of_biotechnology