BIOPHYSICS IN SCIENCE EDUCATION: DEVELOPMENT OF AN INTEGRATED SCIENCE MODULE FOR PRE-SERVICE TEACHER

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ABSTRACT

The challenge to teach science education in at the junior high school level is to ensure that all branches of science is integrated and coherent for students. This due to the science module taught in pre-service teacher education are given separately. This study aims develop a module for integrated science course. The module was designed to deliver a coherent integrated science by introducing and using Robin Fogarty's connected model to pre-service teacher in the integrated science course in Lambung Mangkurat University. This study was carried out using 4D (Define, Design, Develop, Disseminate) development model. In the develop stage, validity test, practicality test, and effectiveness test was carried out. For the validity and practicality test, the data is analyzed descriptively, while the effectiveness test was analyzed using paired sample t-test. This study found that using Robin Fogarty's connected model to create an integrated science module could result in a valid, practical, and effective module. The module also provide and a comprehensive example on how to use the connected model to different scientific concepts. Further study to explore other ways to integrate scientific concept should be made to provide students with more reference on how to integrate different concepts from different scientific branch.

Keywords: integrated science; connected model; robin fogarty; module development; pre-service teacher

INTRODUCTION

The challenge to teach integrated science in at the junior high school level is to ensure that all branches of science is integrated and made coherent for students. To answer to this challenge, teachers need to be knowledgeable not only on one science branch such as, biology, physics, or chemistry only, but also understand how all concept are interrelated to one another.

The researcher found during their service as lecturer at the Science Education Study Program, Faculty of Teacher Training and Education, Lambung Mangkurat University, most of students who would become teacher candidates (also known a pre-service teachers) still had difficulties in teaching integrated science. Authors found this issues during observing pre-service teachers teaching performance in Teaching Practice course (*Program Praktik Lapangan*). They are able to skillfully teach one science branch, for example when teaching about dynamic electricity, yet unable to make a direct connection about electricity concept with neuron system, despite the Indonesia's 2013 Curriculum demands that both concept being taught simultaneously (Kemdikbud, 2018). Pre-service teachers can only explain about the neuron from the biological structure, and did not elaborate further why both concept were taught simultaneously despite the connection being obvious (neuron system's physiology can trigger electric current within the body) (Cameron et al., 2006). Teaching both concept as a separate concept like that result in less coherent arrangement of teaching materials, and made the learning less holistic compared to the better alternative.

It is no wonder that 15 years old Indonesian students scored low among all

of the OECD's nation in PISA score for science literacy. More than a half of Indonesia's students participating in PISA's test for scientific literacy requires help to engage in science subject, also known as low-achieving students (OECD, 2019b). Scientific literacy is defined by three competencies: explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically. The first competencies is the one that require competencies, meanwhile the second and third competencies require more than knowledge: depend on an "understanding of how scientific knowledge is established and the degree of confidence with which it is held" (OECD, 2019a). However, one certain thing is that all of this requires knowledge. Teachers' ability to make connection between one concept to another is When teachers are unable to deliver scientific knowledge that is coherently integrated, it could contribute to students' inability to explain phenomena scientifically (Schlotterbeck et al., 2020; Scott et al., 2011), which one competence of scientific literacy.

After examining the curriculum, the problem might be stemmed from the fact that these pre-service teachers were taught the branches of science separately. When the knowledge being taught separately, it become isolated from one another. Although the students has passed prerequisite courses of several science knowledge branches, such as physics, chemistry, and biology, there are still many students are still not able to flexibly explain integrated concept.

According to SOLO taxonomy, the ability to make relation between concepts is the fourth level out of five level of learning performance (Biggs & Collis, 1982). It is considered as higher end performance level. Reflecting on Indonesia's use of revised Bloom learning taxonomy, to ensure learning happens, the teacher must deliberately plan the learning to happen to ensure that the students are taught as planned and attain the desired competence (Purwantini et al., 2017). When no planning was made, no one can be sure that learning would occur.

One of the chance to taught pre-service teacher on how to connect different concepts from different branches of science is to deliberately teaching them on how to make integrate scientific concepts through Integrated Science course. Integrated science course is an existing course in the 4th semester at the Science Education Study Program, Faculty of Teacher Training and Education at Lambung Mangkurat University. The aim for this course is that students are able to apply the integrated science curriculum model in science learning through effective and efficient planning and teaching practices.

In the learning process, this course uses Robin Fogarty's book entitled "Integrated Curricula"(Fogarty, 2009) as a reference book. This book is an English language book that has not been officially translated by a local publisher. Practically, student access to the book is limited by the ability of students to understand English texts, and the explanation given by the lecturer through power point slides. Besides, the book itself mostly discuss about the concept, without providing a comprehensive and complete example on how to implement each model to integrate the curriculum (Fogarty, 2009).

The absence of teaching materials that can be used as a guide for pre-service teachers has the potential to result in low achievement (Price-Baugh, 1997). Meanwhile the availability of context rich textbook result in better achievement (Bennett & Lubben, 2006). Developing a

module that could not only explain the theory but also provide contextual example that could become the benchmark for the students to implement the way to teach integrated science becomes urgent, not only for their professional development but also for the sake of their future students in junior high school. Hence, this study aims to develop a module for integrated science course, which contains the theory on how to integrate the different science concepts and a comprehensive example of when the theory is implemented to the curriculum.

METHOD

A development research was conducted to create the integrated science module. Thiagarajan's 4D development model (1974) was used for the development process. There were 4 steps to 4D model, namely Define, Design, Develop, and Disseminate. During the develop step, this study check for module's validity, practicality, and effectiveness.

To check whether the module is valid during the Develop stage, this study conducted construct validity test involving three experts as validators (Plomp, 2013). The validators in this study are experts in biology, physics, and learning media experts. The validity test use validity sheet which contains questionnaire with Likert scale answer. There are 5 aspects being evaluated by the validators within the questionnaires: 1) Visual design, 2) Format, 3) Content, 4) Language, 5) Presentation, 6) Conceptual integration. The validity test were analyzed descriptively. An average score were calculated for each aspects. The average score then interpreted using the following category.

Tabel 1. Validity Criteria

No	Interval	Category
1	$3{,}25 \leq x < 4{,}00$	Very Good
2	$2{,}50 \leq x < 3{,}25$	Good
3	$1{,}75 \leq x < 2{,}50$	Enough
4	$1{,}00 \leq x < 1{,}75$	Lacking

To check the reliability of the validity test, this study use Borich's inter-rater reliability test (Ibrahim, 2005). The following formule of Borich inter-rater reliability test was used:

$$\textit{Percentage of Agreement}\ (\mathrm{R}) = \left\{1 - \frac{A-B}{A+B}\right\} \times 100\% \qquad \text{(Ibrahim, 2005)}$$

A = The frequency of aspects observed by observers who give high frequencies

B = The frequency of aspects observed by the observer giving low frequencies

Meanwhile to check the practicality of the module, this study use 2 questionnaire: 1. Interface questionnaire and 2. Content questionnaire. The respondent for the practicality test is 7 pre-service teachers (Plomp, 2013). For the practicality test, the data is analyzed descriptively. Lastly, to check module's effectiveness, a pretest and post-test experiment was carried out. For the effectiveness test, the data is acquiring via test questions containing 10 questions about the content of the module. Pre-service teachers' score were aggregated from the total of right answer. The score is then analyzed with paired t-test using IBM SPSS Statistic 25 (Kadir, 2017). The subject for the effectiveness test are 17 pre-service teachers (Plomp, 2013) of integrated science course students who are also a pre-service teacher in their 2nd year of study. By this time they would already took 2 foundation

of biology courses, 2 foundation of physics courses, 2 foundation of chemistry courses.

RESULT AND DISCUSSION

Result

This study aims to develop a module for integrated science course, which contains at least the theory on how to integrate the science concepts and a comprehensive example when the theory is implemented to integrate different concepts from different branches of science. In the Define step, the thinking process was guided by the mentioned aim. Since the subject for this research is pre-service teacher who are yet to have experience in teaching integrated science, then a module for beginner teacher that is easy to learn should be made.

Based on this consideration, authors explore various ways to integrate learning. Fogarty introduced 10 models to integrate learning as shown in table 1

Tabel 1. Ten models to integrate curricula (Fogarty, 2009: 2)

No	Model	Definitions
1	*Cellular*	Focusing on priorities of each course
2	*Connected*	Making explicit connections with classroom opportunity
3	*Nested*	Targeting multi-dimensional skills and concepts into one lesson
4	*Sequenced*	Rearranging sequence when a topic is taught to coincide with a parallel topic in another discipline
5	*Shared*	Integrating one subject with another through the learner's conceptual eye
6	*Webbed*	Weaving natural and obvious themes of a subject (such as the work of an artist or writer) into the fabric of discipline
7	*Threaded*	Integrating what is taught with cognitive tools, strategies, and technical tools that cross disciplines
8	*Integrated*	Involving interdisciplinary team discussions when planning curriculum
9	*Immersed*	Connections pas experiences and prior knowledge with new information
10	*Networked*	Building new bonds of interest with other experts through networking

Connected model is chosen as the theory to be introduced in this module to the student. Compared to the other nine models, this model can be considered a simpler model to integrate concepts from different branches of science. Connected model's distinctive feature is that it can be used to teach learning materials with many details. Connected model also demand the teacher to make explicit connection between concepts. The key to this model is a deliberate attempt to link various aspects of the curriculum, and does not assume that students will be able to automatically understand the connection (Fogarty, 2009). Looking at the characteristic of science materials in Indonesia, it often require students to master rich scientific concepts, and is arranged in such a way that connection can be made between concepts from different branch of science (Kemdikbud, 2018). Yet, the technical document on creating the lesson plan does not specify on how to integrate different

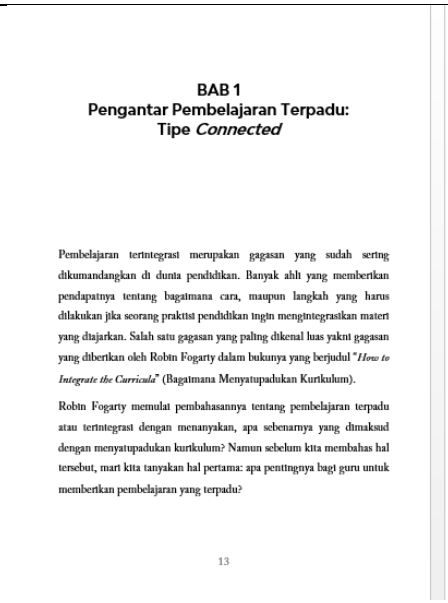
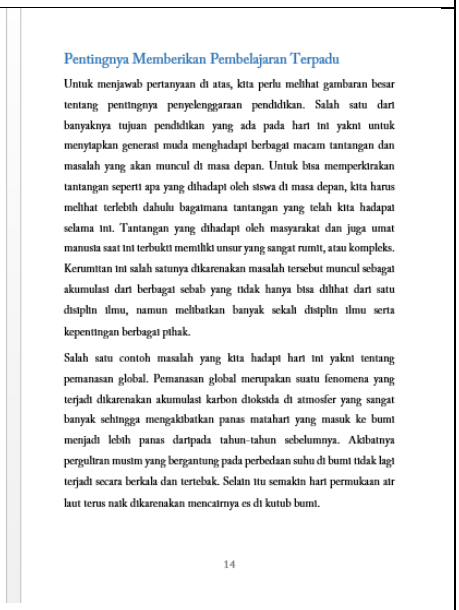
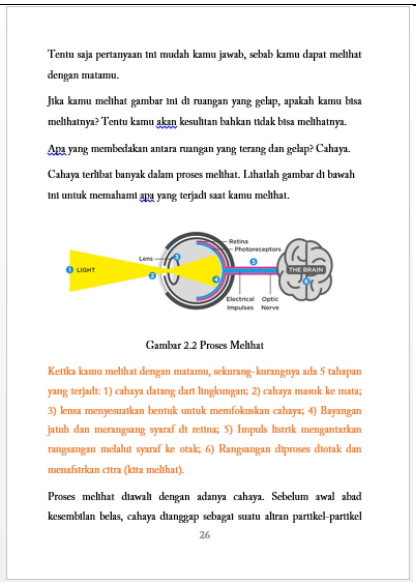
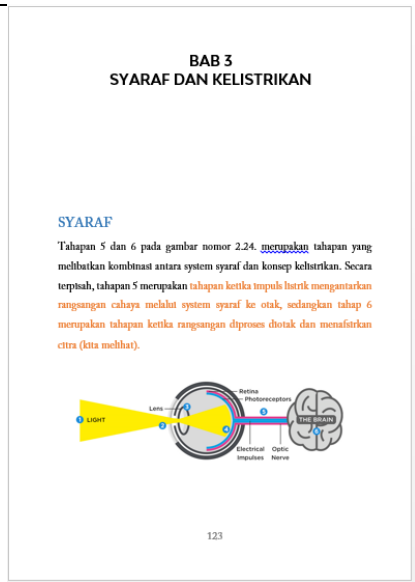
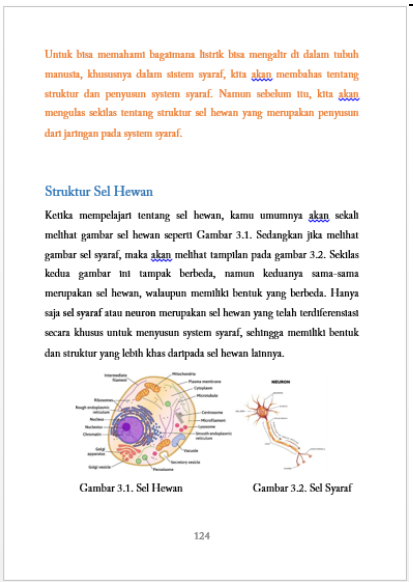
concept classroom practice (Purwantini et al., 2017). To this problem, the connected model's solution is to make explicit the connection between the concepts. This could be done by providing a bridging statement between two related concepts that was usually being taught separately based on the science branches.

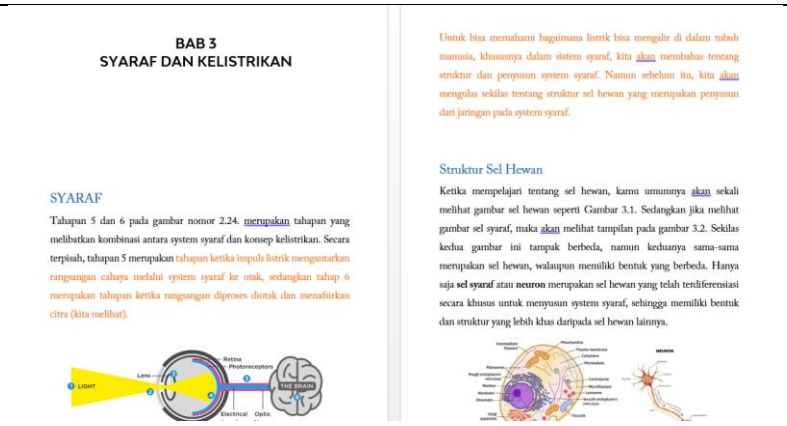
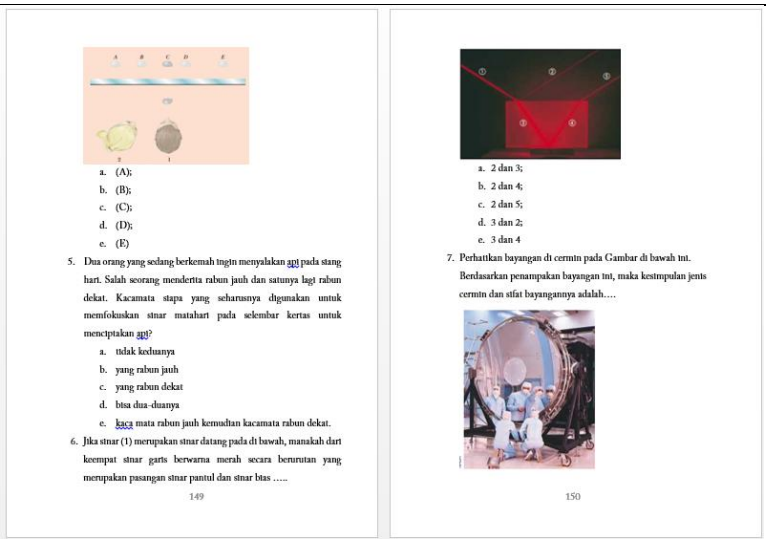
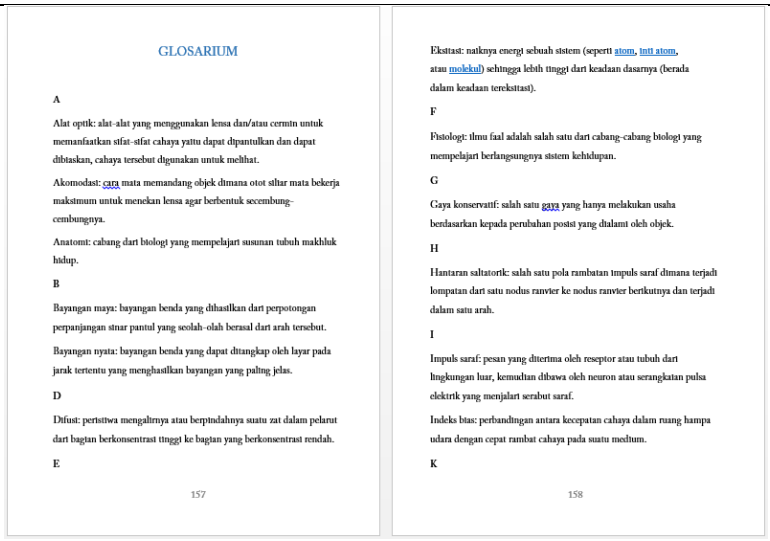
For the second main content, the authors must decide on which science concepts that could be used as contextual example to the students on integrating scientific concepts. After examining the content of the K13 curriculum, the authors decided to pick 4 concepts, namely: Optics, Eyes (senses), Nervous System, and Electricity. Optics and Eyes (senses) is an adequate example as an introductory concept to be integrated, because both concept is often being taught simultaneously. However, when discussion about eyes were used in explaining the concept of optic, it is rare for any science book to further explain what happens after the eyes receive light from the outside world. Does vision happened in the eyes or in the brain? These long and through explanation, which involve connecting many scientific concepts, does not exist in junior high school science book despite all of the basic concepts existed separately within the junior high school curricula.

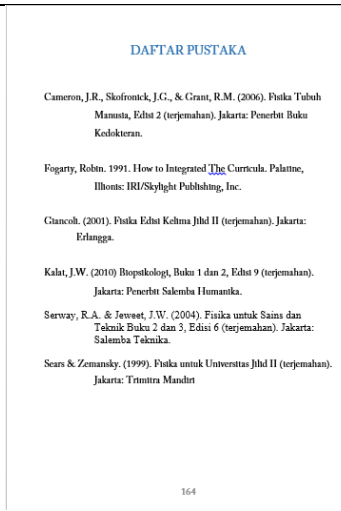
Based on the above thinking process, the authors went to the second step of the 4D, namely the design stage. The design of the module could be seen in the Figure 4. The design of the integrated science module.

Tabel 2. The design of the integrated science module

No	Aspects	Visualization
1	Cover	
	Front and Back Cover	
2	Content	

No	Aspects	Visualization
	Theories about integrated curricula and how to integrate different concepts	 
	Example of integrating the physics and biology curriculum in the vision process: Optic and eyes	 
	Example of integrating the physics and biology curriculum in the vision process: nervous system and electricity	 

No	Aspects	Visualization
	Explicit connection between concepts is written with orange-colored font	
3	Evaluation	
4	Glossarium	

No	Aspects	Visualization
5	References	

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After the module design was finished, author move on to the Develop stage. There are three aspect in develop stage that needs to be measured, namely the validity, practicality and effectiveness.

Table 3. Summary of Validity Test

Aspects	Average score	Descriptor
Visual design	3,93	Very Good
Format	3,90	Very Good
Content	3,80	Very Good
Language	3,93	Very Good
Presentation	3,92	Very Good
Conceptual integration	4	Very Good
Overall	**3,91**	**Very Good**

The result of the validity test could be seen in table 3. Summary of Validity Test. The results of the validation test show that the module is valid, both from the module design criteria, format, material, language, presentation and integration of science with an overall validity score of 3.91 out of a total score of 4 which means this module is very good. The average reliability of the validators, calculated using Borich's inter-rater reliability formula for all criteria is 97%, which means the validity test result is reliable.

The validators also made some small corrections, such as in typos, phrases used, and offered suggestions such as

"…need to be equipped with learning objectives, evaluations for topics presented in physics and biology material, or evaluations can also be based on the results of the integration of these two things in science material,"

"…provide a more comprehensive bridging on the transition between optics concepts to eye's biology concepts,"

"… it will be more tidy if the paragraph use 'justified' format… Small mistakes only on format consistency…"

"… I am glad because there is connection between optics, nervous system. If possible add more connection between optics to other discipline."

"Don't use too small pictures, so it could be easier to look at…"

After the module was valid, the authors check for module's practicality, based on interface and content (Plomp, 2013). Interface test results show that most respondents find modules to be good as well as attractive. This can be seen from the score which shows that 8 out of 10 aspects of the assessment get a score of 100%. The result of interface test could be seen in table 4. Summary of interface test.

The content test found that for question types that are positive to the characteristics of the module, the response gives a score of starting from neutral to strongly agreeable. As for the types of questions that are negative to the characteristics of the module, the responses provide scores ranging from neutral to strongly disagree. This response questionnaire shows that this module can be accepted by respondents as a module used for integrated science learning. teh result of content test could be seen in table 5. Summary of content test.

Table 4. Summary of Readability Test

Aspect to evaluate	Interesting/Good	Uninteresting /not good/must be changed with….
Is the content of this module interesting?	100%	0%
Is the physical appearance of this module attractive?	100%	0%
Types of fonts used by Adobe Caslon	100%	0%
Font size 11	100%	0%
Linguistics		
a. Readability of the language or language used according to the age of the student	100%	0%
b. Terms used are precise and understandable	100%	0%
c. Using consistent terms and symbols	80%	20%
d. Using communicative language	100%	0%
e. Using effective sentences	100%	0%

Table 5. Summary of Content Test

Question types	Evaluated aspect	SD	D	N	A	SA
+	Integrated Modules caught my interest	0%	0%	0%	100%	0%
+	I can link learning materials with science literacy	0%	0%	0%	100%	0%
+	The way the information is organized in the integrated module helps me in focusing my attention on learning	0%	0%	0%	80%	20%
+	Integrated module explains a concept using illustrations in everyday life	0%	0%	0%	60%	40%
+	Module size adequate to my needs	0%	0%	0%	100%	0%
+	The subject matter related to science literacy in this module is interesting	0%	0%	0%	100%	0%
+	The content of the material description in the module is in accordance with the learning objectives	0%	0%	0%	80%	20%
-	The size of the writing in the module is so small that it makes it difficult to read	0%	40%	60%	0%	0%
-	The writing style of the subject matter description in the integrated module is still boring and difficult to understand	0%	40%	60%	0%	0%
-	This module presents information that does not suit my needs	40%	20%	40%	0%	0%
-	The integrated module made me uninterested in following light and optics lessons and the nervous system on the process of seeing	60%	20%	20%	0%	0%
+	The integrated module encouraged me to search further for information about light and optics and the nervous system on the process of seeing	0%	0%	0%	60%	40%
+	The integrated module encourages me to be enthusiastic in doing practice questions and formative tests independently	0%	0%	20%	80%	0%
+	The presentation of the material in the integrated module helped me in understanding the concept of learning	0%	0%	0%	100%	0%
+	The integrated IPA module makes it easier for me to understand the material	0%	0%	0%	100%	0%
-	The questions given in the integrated module are too difficult	0%	20%	60%	20%	0%
+	I was able to learn using this integrated module independently because the language used is so simple that it is easy to understand	0%	0%	0%	100%	0%
+	Learning can be completed on time after using this module	0%	0%	0%	100%	0%
-	I have difficulty studying this module because the preparation of the content of the learning material is not in order	0%	60%	40%	0%	0%
-	Understanding of the material learned becomes slower when using this module	0%	40%	60%	0%	0%

SD=Strongly Disagree, D=Disagree, N=Neutral, A=Agree, SA=Strongly Agree

Effectiveness of the module was checked based on pretest and post-test score. Paired T-test was carried out to analyze the test scores. The paired t-test shows that there is a significant increase to student's score after they use the module to study (sig.<0,05). The result of the paired T-test could be seen in Table 6.

Table 6. Result of paired T-test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	PRETEST - POSTTEST	-1.625	1.360	.340	-2.350	-.900	-4.779	15	.000

After the module is known to be valid, practical, and effective, the module is ready to proceed to the Disseminate steps. For the dissemination, the module is made available online at University's Learning Management System.

Discussion

Preparing pre-service teacher to teach requires a deliberate effort and careful planning. Unable to do so could result in unprepared new teachers who are unable to effectively facilitate the acquisition of knowledge for students, hence damaging the effort to develop students' scientific literacy (Global Education Monitoring Report Team, 2014; Keller et al., 2017). Equipping the pre-service teachers with adequate learning materials becomes one of an important ways to ensure that they have reference to be made example to. Previous study has found that the lack of adequate learning materials could correlates with low learner's achievement (Ahmed et al., 2024; Price-Baugh, 1997) while providing students with context rich learning materials improve learners' achievement (Bennett & Lubben, 2006).

In science book which was arranged based on concepts, the text would contain description of the concepts. This types of expository text is common to be found in science book (Begoray & Stinner, 2005). For example, in a chapter which explain about Force, the text would contain a sole explanation about force, and aspect that is involved in it (e.g. mass, acceleration), and rarely deviated to other concepts of branch of science, except to make an example to it (e.g. movement of animals). This is how science book are often arranged, a concept followed by another concepts that are rarely related to one another. In other words, it is isolated from one chapter to another chapter. It was arranged according to needs of the curriculum, as mandated by educational board that the book adhered to.

When the exposition of the various concepts within a science book is created based on certain concept, "a bridge" would be necessary to be made to connect between different concepts. This bridge could be made by employing the connected model principle to arrange the text. The main characteristic of connected model is to make explicit the connection between the concepts that is initially not obvious. For example, when optics and senses are being taught separately, the connection between light, optics and eyes were not made explicit, and did not create a single comprehensive exposition. However, when the text is more developed around the context of the process of vision, it could involve concepts from optics, light, as the source of stimulation to eyes as the receptor of stimulus (Giancoli, 2005; Kalat, 2015). All the concept could be discussed as coherently intertwined information which provide big picture for students to learn.

There are two challenges in developing this module. First, to introduce the ways science concept could be connected to one another. This module earlier chapters explain on the general idea on why integrated learning is necessary, and the various ways it can be done. This part largely adapt the Fogarty's book which has been used for this course from the previous years. The book then focused only to the connected model. The model was chosen since it could be considered as one of the simpler ways to integrate concepts because it does not departed to far from the current practice in science book and science education. Teachers only have to understand the different concepts and the make bridging to connect between the concepts. This is aligned with the spirit of connected model, which was "to make explicit the connection between the concepts." (Fogarty, 2009).

The second challenge is to provide example of the theory that is used to answer the first challenge. In the latter part of the book, the authors demonstrate how the connected module could be implemented in Indonesia's K13 Curriculum. The authors make sure that the content of the book could be conveyed coherently, so that it makes one long contextual story of a scientific phenomenon. In this book, the phenomenon is about human vision, which involved 4 originally separated concepts: Optics, Eyes (senses), Nervous System, and Electricity. The scientific exposition was arranged based on literature study of various science book, such as Physic of Human Body (Giancoli, 2005) which was mostly used by health practitioner training and Biological Psychology (Kalat, 2015) which was mostly used in psychologist training. The exposition were centered to how intriguing the vision works. The module provide a comprehensive exposition while also make notes on the "bridges" that connects the concepts with different font color to demonstrate pre-service teachers on how the connection using connected model is made within the context of vision.

Previous studies that report about the development of integrated science module such as in Sunarno et al. (2016) has not reported on which concepts that is integrated within the module while also using the connected approach. While other studies, such as by Linda et al. (2021) reported that they used the connected model to one topic, namely the energy topic. This study is different compared to the studies because this study reported that it is possible to create an integrated module by integrating four concepts of science using the connected model.

Inclusion of a comprehensive example is important to ensure that the pre-service teachers' has an example to refer to when they are teaching integrated science. It is also to ensure that the pre-service teacher did not mislead their future students, and provide them with enough knowledge with interrelated concepts that could help the teachers to explain scientific phenomenon to their future students, hence facilitating the development of students' scientific literacy (Dewi et al., 2021). Similar attempts to create a coherent and contextual book to facilitate students' deep and holistic understanding about science and facilitate the development of students' scientific literacy has been previously done. A nation-wide study involving hundreds of experts in science and education was conducted to create contextual and coherent biology, physics, and chemistry modules for A-level students was carried out in the United Kingdom (Bennett & Lubben, 2006; Hall et al., 2003; Swinbank, 1997). Those books has been used as a reference on creating integrated science. Studies have shown that

using those books affect students understanding and interest in learning science (Bennett & Lubben, 2006). Reflecting to these projects, authors expect to develop more content for the module to explore other ways to integrate science concepts and its example so that the pre-service students have more example to use as reference to teach in the classroom.

CONCLUSION

This study was conducted to answer the problem of the lack of teaching modules for integrated science course that could prepare pre-service teachers to teach integrated science in science classrooms. Creating a coherent module that could provide knowledge on how to integrate scientific concepts and demonstrate how it is implemented in a form of contextual scientific phenomenon has become a challenge. However, this study has successfully develop a module which contains the theory on how to integrate the science concepts and a comprehensive example when the theory is implemented to integrate different concepts of from different branches of science. This study use Fogarty's the connected model as an introductory model to integrate different scientific concepts. The module also provide and a comprehensive example on how to use the connected model to different scientific concepts. Further development study is required to explore other ways to integrate scientific concept to provide pre-service teachers in all teacher training faculties with more reference on how to integrate different concepts from different scientific branch.

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