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Development of Physics E-book Based on Technological Pedagogical Content Knowledge (TPACK) on Thermodynamic Laws Topic

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Abstract

This research was developmental research with aims to develop, knowing validity and practicability of thermodynamics e-book based on TPACK. This research was using 4D models and did only as far as develop step. The result based on 4D model steps were (1) Define produces task analysis to fulfil 21st century skill, (2) Design produces 2 product which are teacher book and student book, (3) Develop step produces result of validation and the last product (e-book/flipbook for teacher and student). Expert validation showed the teaching instructional material is valid, learning planning is valid, Content Representation is valid, and e-book is valid. 89,5% students responded this e-book very interesting. This e-book can be said quite practically. Limited trial and small experiment were carried out in one of class in senior high school of one Ngoro Mojokerto and concluded that the increase in the stabilization of sub-topic introduction to Temperature and the Thermodynamics Zero Low is high through the activity of comparing (*Let's Compare*). Students can learn thermodynamics by keeping up with science and technology developments by this e-book. The practical benefit is helping the success of learning process carried out at school and home because e-books are provided in 2 forms, teacher book and student book.

Key words: e-book, thermodynamics, TPACK

INTRODUCTION

The physics learning process should start by exposing students to real problems in daily life and how to solve those problems so that student knowledge increases and understands physics more deeply (Haji, Safriana, & Safitri, 2015). That is why conceptual understanding is one of the newest and most extensive areas of study in physics education research (Docktor & Mestre, 2014).

Student difficulties in learning physics is lack of conceptual understanding and found on some topics like light and optical instruments (Widiyatmoko & Shimizu, 2018), Force and Motion (Saleh & Mazlan, 2019) and Thermodynamics (Djarod, 2015; Hakim, Liliasari, & Setiawan, 2016; Reynolds & Perkins, 1996). Factors that cause misconceptions are the complexity of concepts, daily experiences, books, the language used (Widiyatmoko & Shimizu, 2018), students cannot prove scientifically acquired knowledge (Maulini, Muliyani, & Kurniawan, 2016), and the teacher's lack of creativity and conscientiousness in exploring student ideas (Irwandani, Rofiah, & Sani, 2015), physics teachers having difficulty organizing the material they have missed (Rahmawati, Rustaman, Hamidah, & Rusdiana, 2018) and the

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misconceptions of teachers (Widiyatmoko & Shimizu, 2018).

Misconceptions about science are an important issue for teacher development in science education, in particular the curriculum and teaching strategies must be integrated in an appropriate way (Prachagool & Nuangchalerm, 2019). In the end, this misconception leads us to teaching physics / science by teachers. The teaching of science has five important components that are interrelated in a highly complex way (Nozoe & Isozaki, 2020). Which are those components conceptualized against a framework called Pedagogical Content Knowledge (PCK).

Koehler & Mishra (2008) discussed a new view of teacher knowledge needed for teaching in the 21st century. They incorporate technology into teaching based on the PCK introduced by Shulman before, then we called this framework as Technological Pedagogical Content Knowledge (Guzey & Roehrig, 2009).

In line with (Oktasari, Jumadi, Warsono, Hariadi, & Syari, 2019) which stated that the current issue of 21st century competence is the development of student abilities covering 6C and integrating digital technology literacy into learning, has a significant influence on students' conceptual understanding of physics, interactive e-book (presenting all educational add-ons such as presentation tools, interactive boards, video illustrations, animations, or audio files becomes a part of itself) that improves student learning process (Binas, Michalko, & Novak, 2012), and TPACK dynamics for technology integration in science teaching (Koehler & Mishra, 2010), so we develop an e-book based on TPACK on thermodynamics law topic, also for knowing the validity and the practicability of this e-book.

METHOD

This research is a development research by adapting the Four-D development model (Define, Design, Develop, and Disseminate) developed by Thiagarajan (Yanti, Kuswanto, Habibi, & Kinasih, 2020). Development is carried out only up to the third stage. Collecting research data using product trials of the development results to determine the feasibility and practicality of the product.

The instruments used were: (1) Product validation questionnaire, (2) E-book readability questionnaire, (3) Learning implementation questionnaire, and (4) multiple choice question to recognize the introduction of Thermodynamics Zero Law. The product validation questionnaire is used to find out the validity of the product where the data observed include the feasibility of the e-book, content of product, lesson plans, and core with the respondents are material and media experts (physics teacher and physics lecturer). E-book readability questionnaire to determine the level of e-book readability, where the observed data are attractiveness and ease of using the products, with 14 students of SMAN 1 Ngoro Mojokerto as respondents. The learning implementation questionnaire was used to determine the practicality of the e-book in learning, the data observed were the level of implementation and ease of use of the e-book by students, this was carried out by a physics education student as a respondent. Multiple choice questions were used to identify whether let's compare section in this e-book can work well. But it is limited only for sub-topic thermodynamic zero law since this is for small scale trials. Students also worked on some section in this e-book for limited trials.

E-book feasibility analysis is carried out by tabulating all the data obtained for each component of the assessment items available in the research instrument then calculating the average total score of each component using Equation (1):

$$\bar{x} = \frac{\sum x}{n} \qquad (1)$$

(Purwanto, 2002; Simatupang, 2016)

With

$\bar{x}$: average value

$\sum x$: the total score of the assessment answers

n : number of validators or respondents

Then, given interpretation and decision using the criteria shown in Table 1.

Table 1. Criteria of Validity Criteria

Average	Validity / Appropriate Criteria
3.28 – 4.00	Valid/ Appropriate
2.52 – 3.27	Valid enough/ appropriate enough
1.76 – 2.51	Less valid/ less appropriate
1.00 – 1.75	Invalid/ not appropriate

Source: (Pradana, 2015)

E-book practical analyzed using Equation (2).

$$NP = \frac{\sum R}{\sum SM} x\ 100\% \quad (2)$$

(Purwanto, 2002; Simatupang, 2016)

With

NP : Percentage value

$\sum R$: Total score for each indicator

$\sum SM$: If every statement got score 4

Then data was changed to be five scale, the reference showed in Table 2.

Table 2. Five Scale Category

Interval	Category
0% - 20%	Very less worthy
21% - 40%	Less worthy
41% - 60%	Quite worthy
61% - 80%	Worth
81% - 100%	Very worthy/very interesting

(Riduwan, 2014; Simatupang, 2016)

RESULT AND DISCUSSION

This research is relevant to research by Hansson, Leden, & Thulin (2020) which states that book is important to teach natural science to student. Reading books was an important part of this participant's life and enabled to engage in an exchange of ideas that we don't get opportunity to have in our daily life (Henriksson and Laakso, 2019). Result of development was grouped based on development procedure. Define step consist of front-end analysis, student character analysis, task analysis, concept analysis, and specification of learning indicators. Front-end and student character analysis are reference, survey of physics teaching materials in schools and character of class XI MIA 1 SMAN 1 Ngoro Mojokerto. Task analysis produces 4 skills in HOTS. Concept analysis produces concept map and CoRe. Specification of learning indicators produces learning indicators.

Design step produces thermodynamics e-book which are divided into Student Book and Teacher Book. So, they can be used as teaching materials for grade 11 students in the second semester at high school level, especially students majoring in science where thermodynamics is one of the topics in physics. The sections of student book are cover, preface, table of contents, instructions for user, PhET, concept map, problem, let's compare, show the result, clarification, example, questions, complete these concept map, let's try dan let's discuss together, reasoning, ask column, summary, quiz, glossary, and references. The sections of teacher book are cover, preface, table of contents, instructions for user, syllabus, Content Representation, development of competency achievement indicators, learning implementation plan, preparation of question items, discussion of let's compare and show the results, discussion of complete these concept map, question assessment rubric, reasoning assessment rubric, discussion of let's discuss together, quiz grids, and references.

Develop step divided to expert validation, revisions, readability test results, limited trial, and small-scale trial. Expert validation included e-book validation, teaching materials validation, learning implementation plan validation, and Content Representation (CoRe) validation. Limited trial was conducted by asking 31 students to work on some parts of the e-book. small-scale trials were carried out by giving 8 multiple choice questions regarding the introduction of thermodynamics zero law and comparing changes in students' answers after being given the let's compare and show the result section. E-book validation result shown in Table 3.

Table 3. E-book Validation Result

Indicator	Validator			Average	Criteria
	V1	V2	V3		
Content quality	4	4	4	4	Valid
Language	4	4	4	4	Valid
Compliance	4	3.6	4	3.87	Valid
Use	4	3	4	3.87	Valid

The average is 3.88 which is valid. So, this e-book can be said have fulfilled eligibility criteria.

Validation results of teaching materials shown in Table 4.

Table 4. Teaching Materials Validation Result

Indicator	Validator			Average	Criteria
	V1	V2	V3		
Application of analogy for Temperature and Thermodynamics Zero Law	4	3.67	4	3.89	Valid
Application of Analogy for Heat and First Law of Thermodynamics	4	3.67	4	3.89	Valid
Application of Analogy for Thermodynamics Second Law	4	4	4	4	Valid
Implementation of Pedagogical Content Knowledge	4	3.5	4	3.83	Valid
Material breadth	4	4	4	4	Valid
Depth of Material	4	3.25	4	3.75	Valid
Accuracy of Material	4	3.33	4	3.78	Valid
Let's Try for thermodynamics first law	4	4	4	4	Valid
Let's Try for thermodynamics second law	4	2	4	3.33	Valid
Example	4	3	4	3.67	Valid
Questions	4	3	4	3.67	Valid
Reasoning	4	3	4	3.67	Valid
Demands of 21st century	4	3.33	4	3.78	Valid
Layout	4	3	4	3.67	Valid
Color	4	3	3	3.33	Valid
Figure	4	3.5	4	3.83	Valid
Writing form (font)	4	4	3	3.67	Valid
Consistency	4	3	4	3.67	Valid
Student centered	4	3	4	3.67	Valid
Variation of presentation	4	3	4	3.67	Valid
Completeness	3	3.875	3.75	3.54	Valid
Language eligibility	4	4	4	4	Valid

In this study, the initial title in the development of e-book is, e-book based on analogy and PCK. However, 2 of the experts and a supervisor stated that the apperception in each sub-material is interesting, but it is too forced to be called as an analogy, so that the analogy part can be changed to 'other things' where the author decided to change the title of the apperception to 'let's compare'. While three of validators and two supervisors stated that this e-book was not based on PCK, but TPACK. By looking at the implementation TCK is technology in presenting scientific disciplines, where there is PhET to explore abstract phenomena in thermodynamics, and TPK implementation is a consideration of the influence of the use of technology in teaching, by making one between books and PhET simulations in e-book so that they can be accessed by teachers and students anytime and anywhere. The overall average value is 3.74 sand is included in the valid criteria. As well as the learning implementation plan, also got a score of 3.78 which is included in the valid range. Learning implementation plan should be validate because the content from the book is important. Books are important and connected to the classes termly and yearly curriculum themes (Papen, 2019). The results of expert validation for RPP are presented in table 5.

Table 5. Learning Implementation Plan Validation Result.

Indicator	Validator			Average	Criteria
	V1	V2	V3		
Subject identity	4	4	4	4	Valid
Competency	4	4	4	4	Valid
Indicators of competency achievement	4	3	4	3.67	Valid
Learning orientation	4	4	4	4	Valid
Learning material	4	4	4	4	Valid
Learning model	3	3	4	3.33	Valid
Learning step	4	3	4	3.67	Valid
Learning resources	4	3	4	3.67	Valid
Assessment	4	3	4	3.67	Valid

Then, the last expert validation is for Content Representation (CoRe) which is drawing TPACK for this e-book. In line with (Nilsson & Karlsson, 2019), CoRe and digital technology can be used as a tool for capturing PCK. Quality instruction requires PCK and affect student learning outcomes positively (Neumann, Kind, & Harms, 2019). TPACK is important to analyze based on Valtonen, Sointu, Kukkonen, Makitalo, & Hoang (2019) statement to see if technology, content, or pedagogical areas are stronger. Four areas that drive change in teacher education are knowing your students, data and assessment literacy, content and pedagogy, and field-based experience. In content and pedagogy area, TPACK is related to technology and equity-based pedagogies (Floden, Richmond, & Salazar, 2020). Average value is 3.73 and included in valid range. The result showed in Table 6.

Table 6. CoRe Validation Result

Component	Validator			Average	Criteria
	V1	V2	V3		
Drafting Big Idea	4	4	4	4	Valid
Big idea A	4	3.125	4	3.71	Valid
Big idea B	4	3.25	4	3.75	Valid
Big idea C	4	3.25	4	3.75	Valid
Big idea D	4	3.25	4	3.75	Valid
Big idea E	3	3.25	4	3.42	Valid

Product revision are carried out based on qualitative data on the suggestion sheet that put by expert/validator or during validation process. Revision have been done on teacher book so that it is made softer. And then changing analogy to Let's compare. Also, title of study, this e-book is based on TPACK, not PCK and analogy.

Students showed positive respond through 42% said agree and 58% claimed very agree for 16 statements on e-book readability questionnaire. Then, percentage value is 89,5%. The percentage and statements shown in Table 7.

Table 7. E-book readability result by student.

Statement	R
I'm interested to do *Let's Compare* in this e-book	53
I prefer to compare first before than directly being asked the opening questions	54
By *Let's Compare*, I find it easier to imagine physics phenomena in real life	54
PhET makes this e-book more interesting	49
I like topic presentation from *Clarification*	48
Example part increase topic understanding	51
Questions not too much, so this e-book doesn't make me boring	47
I prefer to completing concept map like in this e-book than drawing concept map by my self	50
I like how this e-book add *asking column* under *reasoning* so I can write my question when I don't have opportunity to ask directly to my teacher	45
Let's try is easy to do	49
The cover is interesting	53
The color of teaching materials also gives its own appeal	46
Every picture looks clear and interesting	49
When I learn using this e-book, I feel excited to listening the topic	53
This e-book is easy to use	50
I love learning physics using this e-book	51
NP	89.5%

Aspects observed in the learning implementation questionnaire sheet are students did every part of this e-book well, discuss with teacher, each group have opportunity to present their discussion result, can understand thermodynamics law topic, can conclude their learning, and easy to use this e-book. There are 12 aspects and grading scale ranges from 1-4. The total score is 44, so the percentage is 91.67%.

Limited trial and small-scale trials were carried out in one of class in Senior High School of One Ngoro Mojokerto. Limited trial was conducted by implementing this e-book for 31 students to work on. They can easily work on the questions, reasoning, and complete these concept maps section.

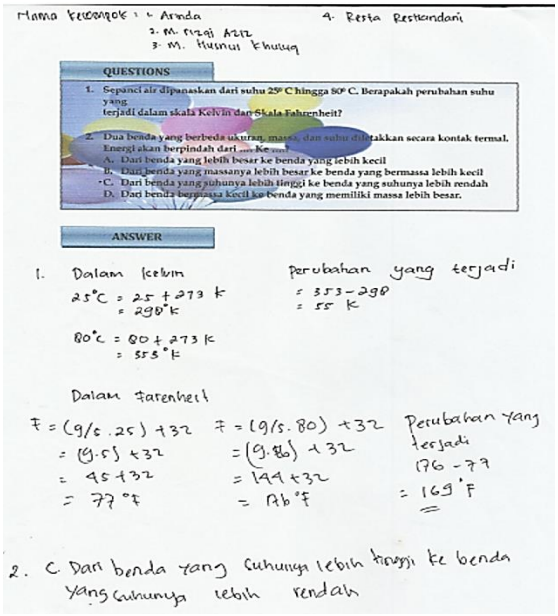

Figure 1. Students' work on *question* section

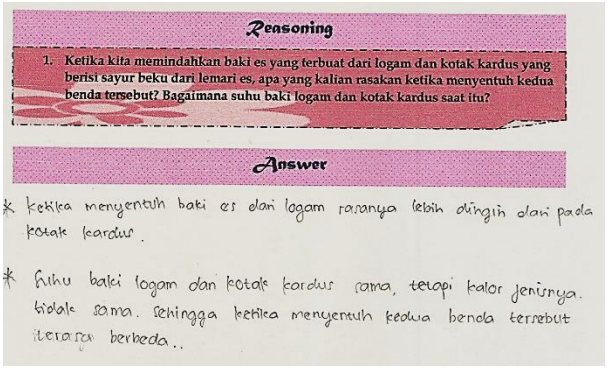

Figure 2. Students' work on *reasoning* section.

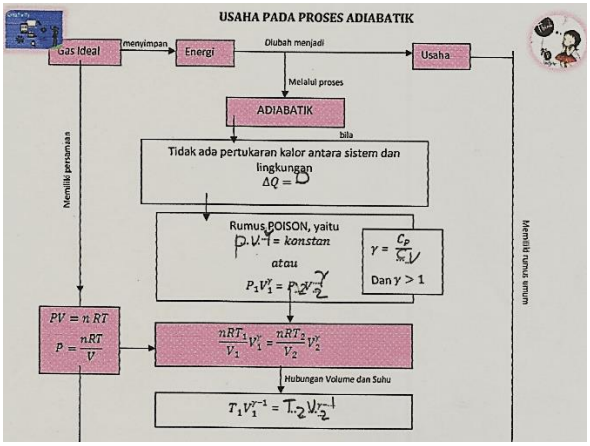

Figure 3. Students' Work on *Complete These Concept Map* Section**.**

Small-scale trials were done by using show the result and let's compare section. Previously, student had studied zero law thermodynamics but when given 8 multiple choice questions about the introduction to these sub-topics, the student had difficulty answering. Meanwhile, after the students filled let's compare and show the result section in this e-book, almost all students answered correctly on the same 8 questions. Comparison of student scores before and after doing let's compare to identify the thermodynamics zero law is presented in the Table 8.

Table 8. Comparison of students' scores in recognizing the zero law of thermodynamics.

Student	Score	
	Before doing *let's compare*	After doing *let's compare*
AAFS	25	100
AAMS	50	100
AR	50	100
ANZ	25	100
BOB	25	100
DKI	25	100
DWK	62.5	100
DAL	25	100
DRS	37.5	100
EW	25	100
EF	50	100
FART	25	100
FAM	75	100
HMANN	62.5	100
IDSA	37.5	100
KNM	12.5	100
KBS	37.5	100
LDA	50	87.5
MRA	37.5	100
MHK	50	100
NA	50	100
NBPM	37.5	87.5
NAIP	62.5	100
OMN	25	100
RR	37.5	87.5
RDW	37.5	87.5
RDAN	62.5	100
SPR	62.5	100
TAP	50	100
W	62.5	100
RS	37.5	100

From that table we can know that let's compare and show the result section in this e-book work well. Every student has increased in their score that means we can use comparing model to introducing a sub-topic of thermodynamics. These

sections were using tables and pictures as visual representation that can be a solution to build effective communication to student (Oktasari, et al, 2019).

Figure 4. Let's Compare Section

CONCLUSION

The electronic book developed has met the demands of 21st century and fulfil eligibility criteria (expert validation) and practicality (learning feasibility). This e-book is practical. The strengths of this e-book are the preparation of materials based on CoRe which shows the essential concept of thermodynamic laws, the presentation considers HOTS, and this e-book shows its progress in the development of science and technology in education under the umbrella of TPACK. Core were used to conceptualize PCK where PCK is used to understand the interaction of teachers' knowledge and practices, also knowledge for planning for teaching a particular topic to enhanced student outcome in a particular way, for particular purpose and for particular student (Doyle, Seery, & Gumaelius, 2019). TPACK and resources are needed as key factors for adopting e-learning with a chance of success (Law & Liang, 2019).

I suggest for teachers and/or students who use this e-book to adjust with user instructional for optimal result. The weakness of this e-book is limited only for thermodynamic laws topic and has not been fully tested in a learning. Furthermore, researchers can test the effectiveness of this e-book on student's conceptual understanding.

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