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To cite this article: M A Riandry *et al* 2017 *J. Phys.: Conf. Ser.* **895** 012047

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Developing Statistical Physics Course Handout on Distribution Function Materials Based on Science, Technology, Engineering, and Mathematics

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Abstract. This study aims to produce a valid and practical statistical physics course handout on distribution function materials based on STEM. Rowntree development model is used to produce this handout. The model consists of three stages: planning, development and evaluation stages. In this study, the evaluation stage used Tessmer formative evaluation. It consists of 5 stages: self-evaluation, expert review, one-to-one evaluation, small group evaluation and field test stages. However, the handout is limited to be tested on validity and practicality aspects, so the field test stage is not implemented. The data collection technique used walkthroughs and questionnaires. Subjects of this study are students of 6th and 8th semester of academic year 2016/2017 Physics Education Study Program of Sriwijaya University. The average result of expert review is 87.31% (very valid category). One-to-one evaluation obtained the average result is 89.42%. The result of small group evaluation is 85.92%. From one-to-one and small group evaluation stages, average student response to this handout is 87,67% (very practical category). Based on the results of the study, it can be concluded that the handout is valid and practical.

1. Introduction

According to Physics Education of Sriwijaya University curriculum, statistical physics course has three semester credit units and is taught in semester V [1]. Statistical physics is part of science which describes micro states collection of system of gas, atoms or subatomic particles [2]. It can be viewed as statistics with physical boundary condition, so it needs high abstraction to be understood and many student do not have the abstraction [2]. From informal interview with students of physics education of 6th semester of academic year 2016/2017 at Sriwijaya University who have taken statistical physics course, they had difficulties to understand statistical physics course, especially on distribution function materials. Based on final examination of statistical physics course academic year 2015/2016 which tested out the understanding of distribution functions materials, the achievement of students of physics education were still low with mean score that is 65.07. These difficulties because of statistical physics books are too difficult to be comprehended and not comprehensive enough on the science and technology application materials. If the materials are uninteresting and complicated, then teaching and learning becomes a dull and monotonous activity [3].

STEM is an integrated learning approach of science, technology, engineering, and mathematics. Study shows that this integrated approach can increase learning interest in science and technology lessons. Many benefits have been associated with STEM education, such as providing opportunities for more student-centered, meaningful, engaging, and less fragmented learning experiences involving higher-level thinking and problem-solving skills [4]. Experience in STEM learning can prepare students

for the global economy of the 21st century [5]. Students need a solid STEM knowledge to become ready for employment [6]. STEM country of origin, United States, the application of STEM in the field of education is being held intensively. As the President's Council of Advisors on Scientific and Technology (PCAST) recommended to form the "STEM Master Teachers Corps" that assess and reward 5% of the best STEM teachers in America [7]. PCAST is also planning in the next decade to recruit 100.000 teachers to teach by using the STEM approach [7]. Distribution function materials require deep mathematical and physical skill to be understood and it have many applications in sciences and technologies, such as solar cell and superconductor material. Thus, STEM approach is very suitable to be implemented in distribution function materials.

A lack of commercial materials forces teachers to fall back on their own resources and designing their own teaching materials can enable them to make best use of the resources available in their teaching context [8]. Developing teaching materials by educators can be a solution to the lack of teaching materials. Studies that provide teaching materials have been done, one of them is done by Kurniasari et al [9]. Based on this, it is important to produce teaching materials on distribution function materials which contain also explanation about physics and technology application materials, so the students can get meaningful learning and the objectives of learning can be achieved. Similar with that study, researcher tried to develop teaching materials in the form of handout on distribution function materials based on STEM for Physics Education of Sriwijaya University.
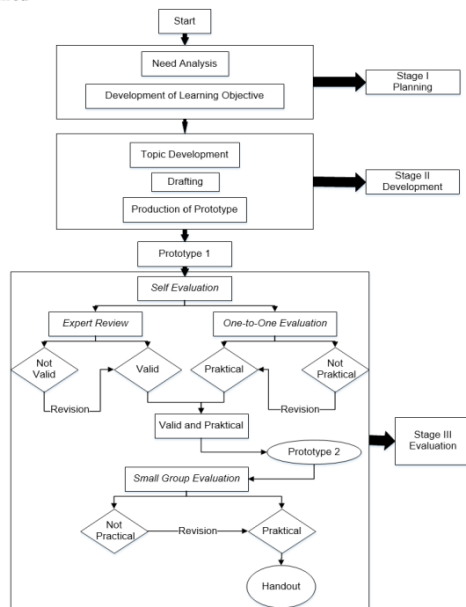
2. Research Method

Figure 1. Study Design Flow

This study is a development research by using the model of Rowntree development. Rowntree development model consists of three stages. They are planning, development, and evaluation stages [10]. Materials that are developed are statistical physics materials with their applications materials. The materials are based on STEM and they are tested on validity and practicality aspects. At the evaluation stage of the study uses Tessmer formative evaluation. The evaluation stages are self-evaluation, expert review, one-to-one evaluation and small group evaluation [11]. Self-evaluation and expert review stages test the validity aspect. One-to-one and small group evaluation stages test the practical aspect. The flow of this study can be seen in Figure 1.

For the data availability in this study, researcher used data collection techniques. They are validations and questionnaires sheets. Subjects of this study are physics eduaction students of 6th and 8th who has taken statistical physics course. There are three criterias which are tested in this study, they are content, design and language criterias by each expert. Each criteria has several indicators. Experts answer the indicators in the form Likert Scale which is shown in the Table 1.

Table 1. Validation category value [12].

Answer category	Score of question
Strongly agree	5
Agree	4
Uncertain	3
Disagree	2
Strongly disagree	1

The indicators are also made in percentage. Furthermore, an average score percentage from expert validation results is obtained by using equation (1) and (2) [13].

1. Determine Criteria of Total Percentage (CTP).

$$CTP(\%) = \frac{Total\ score\ of\ each\ indicator}{Maximum\ total\ score\ of\ each\ indocator}\ x\ 100\% \tag{1}$$

2. Percentage of Final Score from Expert Validations (FSEV).

$$FSEV(\%) = \frac{Total\ score\ of\ each\ criteria}{Maximum\ total\ score\ of\ each\ criteria}\ x\ 100\% \tag{2}$$

Final Score from Expert Validations (FSEV) is also grouped according to Table 2. Suggestions comments are also written on sheets of expert validation and then they were used as reference to n revisions of the handout.

Table 2. Final Score from Expert Validations (FSEV) category [13].

Percentage of Validations (%)	Category
$86 \leq FSEV \leq 100$	Very valid
$70 \leq FSEV < 86$	Valid
$56 \leq FSEV < 70$	Less valid
$0 < FSEV < 56$	Invalid

In One-to-one and small group evaluation stages, students have a chance to fill the questionnaire and give comments and suggestion about this handout. The data obtained through the questionnaire was obtained with Likert Scale which is shown in the Table 3 to get the opinion of students on the handout. Each indicator is made in percentage. Furthermore, an average score percentage from student response is obtained by using equation (3) and (4) [13].

1. Determine Score Percentage of Student Evaluation (SPSE).

$$SPSE(\%) = \frac{Total\ score\ of\ each\ indicator}{Maximum\ total\ score\ of\ each\ indicator} \ x\ 100\%$$

2. Percentage of Final Score from Student Responses (FSSR).   (3)

$$FSSR(\%) = \frac{Total\ score\ of\ student\ evaluations}{Maximum\ total\ score\ of\ student\ evaluations} \ x\ 100\%$$

Table 3. Student response category value [12].   (4)

Answer category	Score of question
Strongly agree	5
Agree	4
Uncertain	3
Disagree	2
Strongly disagree	1

The Result of Final Score of Students Response (FSSR) form one-to-one and small group evaluation stages was made in percentages then grouped according to Table 4. Comments and suggestions from students were filled in the questionnaires, they are purposed to revise the handout to become better.

Table 4. Final Score of Students Response (FSSR) category [13].

Percentage of Questionnaire (%)	Category
$86 \leq FSSR \leq 100$	Very practical
$70 \leq FSSR < 86$	Practical
$56 \leq FSSR < 70$	Less practical
$0 < FSSR < 56$	Not practical

3. Result and Discussion

3.1 Planning Stage

At the planning stage, the result of need analysis is students who have taken statistical physics course have difficulties to understand the physics, mathematics and application concepts which are taught through lecture or discussion. From the students' opinion, the most difficult materials in statistical physics course are distribution functions materials, because they are more complicated to be learned than the others materials. STEM (science, technology, engineering and mathematics) integrated approach is very much suitable for distribution function material characteristics which require deep understanding of science and mathematics to be studied and has many applications in the fields of science and technology. Handout was selected to be developed because it is flexible in form, content and using. Furthermore, at this stage, the syllabus analysis is done by developing indicators of the Standards Competencies (SC) and Basic Competencies (BC), as well as the formulation of learning objectives.

3.2 Development Stage

The result of development stage of this study consists of topic development, drafting and prototype production stages. At the topic development stage, researcher prepared Materials Enrichment (ME) and Content Outline Handout (COH) on the course of statistical physics in distribution function materials. They are used as a reference to drafting handout. ME contains distribution function and application materials which contain STEM (mathematics, science, engineering and technology), they are: Maxwell-Boltzmann distribution function (science and mathematics elements), Maxwell-Boltzmann distribution

function on speed variable (science and mathematics elements), entrophy (mathematics and science elements), Doppler effect (mathematics and science elements), laser (mathematics, science, engineering and technology elements), Bose-Einstein distribution functions (mathematics and science elements), black body radiation (mathematics and science elements), spesific heat capacity (mathematics and science elements), Fermi-Dirac distribution function (mathematics and science elements), electron gas (mathematics and science elements) and metal heat capacity materials (mathematics and science elements). Not all of the materials consist STEM elements such as engineering and technology. Many materials of statistical physics are too statistical matematics. However, not all of STEM elements are needed in the certain materials, but STEM elements can be found in this handout. Beside of that in the class, approaching all STEM elements through engineering design is not always possible [14].

ME focuses on six basics competencies that must be owned by students. While COH contains indicators, learning objectives, materials, assessment and reference. The drafting stage developed handout cover, study guides, table of contents, introduction, main map, content standards, material descriptions, sample questions, exercise questions, exercise key and reference. The handout is written by using 12 pt Times New Roman and it is written coherently based on curriculum of statistical physics with STEM elements combination. The result of production stage is draft which is made in the form of printed material (handout). The result of this development stage is called prototype 1, it contains three chapters about Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac distribution function and their application materials in each chapter.

3.3 Evaluation Stage

Table 5. Expert review stage result.

No	Indicator	Percentage of result (%)
1	Use science element	90,00
	Use technology element	90,00
	Use engineering element	85,00
	Use mathematics element	90,00
	Compliance with basic competencies and learning objectives	90,00
	Compliance with student needs	90,00
	Compliance with handout needs	95,00
	Truth of content of learning materials	90,00
	Benefits to add knowledge	100,00
	Average percentage of content criteria (CTP)	91,11
2	Order of materials	80,00
	Completeness of information	100,00
	Use font: type and size	90,00
	Lay *out*	90,00
	Illustrations, pictures and photos	80,00
	Design view	80,00
	Average percentage of design aspect (CTP)	86,67
3	Legibility	86,67
	Clarity of information	80,00
	Conformity with Indonesian language rules	80,00
	Use language effectively and efficiently	90,00
	Average percentage of language criteria (CTP)	84,16
	Average percentage of total validation (FSEV)	87,31

The prototype 1 that has been developed is then evaluated based on Tessmer formative evaluation. At the self-evaluation stage, the researcher conducted self-checking on the prototype 1. The results are finding typing error in handout, handout cover was still less interesting and images on the sub material were still less clear. After the handout was revised, expert review stage was conducted. At this stage,

IOP Publishing

International Conference on Mathematics and Science Education (ICMScE)

IOP Conf. Series: Journal of Physics: Conf. Series **895** (2017) 012047   doi:10.1088/1742-6596/895/1/012047

prototype 1 was validated by experts consisting of content, design and language aspect. The result of the it can be seen at Table 5. From this stage, the highest score indicator is given benefits to add knowledge that is 100%, because it has many application materials in this handout can extent knowledge about distribution function materials of students. There are four indicators which are given lowest score 80%, they are order of materials, illustrations, pictures and photos, design view and clarity of information indicators, because index of handout, some illustrations, design and material informations were needed to be repaired to become clearlier. The results of expert review stage is 87,31%, so it can be concluded that this handout is very valid based on Table 2. Experts also gave suggestions and comments to make this handout became better. Superconductor (science, engineering and technology elements) and spectrograph materials (science, engineering and technology elements) have been added and some illustrations are repaired to read clearly.

Table 6. Result of one-to-one and small group evaluation stage.

No	Indicator	Percentage (%) of one-to-one evaluation	Percentage (%) of small group evaluation
1	Benefits to add knowledge	93,33	95,56
2	Clarity of information	84,44	85,92
3	Use STEM elements	93,24	91,67
4	Giving motivation	89,83	86,67
5	Use language effectively and efficiently (clear and concise)	89,83	83,33
6	Clear clue of handout usage	100,00	86,67
7	Use of font: type and size	96,66	92,22
8	Lay out	89,83	84,94
9	Illustrations and pictures	80,00	73,33
10	Design view	79,83	74,44
11	Exercise using	86,33	82,22
	Average percentage of score (SPSE)	89,42	85,92
	Average total percentage of student responses (FSSR)	87,67	

The one-to-one evaluation stage was implemented to test the practicality of handouts (prototype 1). This stage is tested on three students of 8th semester in Physics Education Study Program of Sriwijaya University who have taken statistical physics course with different abilities. Those are low, medium and high ablility. Students also gave comments and suggestions about this handout. The result of this stage can be seen on Table 6. Students appreciated this handout because it gave clear clue to use the handout, this indicator got the highest score that is 100%. The lowest indicator score is gotten in design view that is 79,83%, because some fonts needed to be repair and too few pictures in the cover of handout. After prototype 1 was revised based on expert review and one-to-one evaluation stages, prototype 2 was generated and small group evaluation was started.

Furthermore, prototype 2 was tested on students at small group evaluation stage which aimed to test the practicality of handout (prototype 2). In this stage, handout was tested on nine students of 6th semester in Physics Education Study Program of Sriwijaya University who have taken the course of statistical physics. They were divided into three groups based on different levels of ability, those are low, medium and high abilities. The result of this stage can be seen on Table 6. From this stage, the highest indicator score is given benefits to add knowledge that is 95,56%, because many applications in this handout could extent knowledge about distribution function materials. Some illustrations and drawings still needed to be repaired to read clearly, so this indicator got 73,33%. Students also gave comments and suggestions to this handout. Glosarium has been added to help students understand difficult terms in the handout. After prototype 2 was revised based on small group evaluation, prototype 3 was generated and it is the final product of this study. Based on one-to-one and small group evaluation stage, student response of this handout is 87,67% which is based on Table 4, this handout is very practical.

4. Conclusion

Based on the results of development research using Rowntree development model and Tessmer formative evaluation that has been done, it can be concluded that it has successfully been developed a valid and practical handout of statistical physics on distribution function materials based on STEM. Because of that, the handout can be used in statistical physics lesson at Physics Education Study Program of Sriwijaya University and it can be implemented in field test stage to test the effectiveness of this handout.

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