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Development of Students' Perception Instrument of New and Renewable Energy (PINRE)

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(1) a clear statement of the problem the paper is addressing --> explain in
"Introduction" section
(2) the proposed solution(s)/method(s)/approach(es)/framework(s)/ ....
(3) results achieved. It describes clearly what has been done before on the
problem, and what is new.

Abstract

In line with the alteration from fossil toward new and renewable energy sources, students' perception about new and renewable energy become critical and an instrument to measure their perception is needed. This article reports the development process of Students Perception Instrument of New and Renewable Energy (PINRE) through three development phases. After scales, subscales and items were designed, the review by experts and practitioners was done to fulfil and validate the content. A trial process was conducted with 229 students from 8 schools (grades 9 and 12) in three cities involved. Statistical and additional qualitative data suggest that the PINRE is a valid and reliable instrument.

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Keywords: *instrument development, new energy*

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Introduction

In line with global attention to the energy problem, the United Nations Organization established it as one of Sustainable Development Goals (Guterres, 2017). The complexity of energy issues lies in energy production and energy consumption. Energy consumption mainly depends on people's habitual use. This is where energy education plays an important role. For many years, science curriculum around the world highlighted energy as a major topic or core concept (Ministry of Education and Culture of Indonesia, 2017; Yoichi Kiyohara, 2017) and crosscutting concept (NGSS Lead States, 2013). However, the gap between the energy curriculum and real changes in the energy sector still remains (Acikgoz, 2011; Blockstein, Middlecamp, & Perkins, 2015).

One of the major changes is the substitution from fossil to new and renewable energy (NRE) sources that has been going on since around 1800. In the education sector, several interesting learning activities focused on the new and renewable energy issue were developed (Klakayan & Singseewo, 2016; Shrish Bajpai & Naimur Rahman Kidwai, 2017; Walz, Slowinski, & Alfano, 2016). While some studies stated that students' perceptions could be authentic feedback for the learning process (Mulliner & Tucker, 2017), a few studies reported the development of instrument to measure students' perception of NRE.

Moreover, the trend of science-technology-engineering-mathematics (STEM) education suggests designing as an important part of science education in the future (National Academy of Engineering & National Research Council, 2009; National Research Council, 2013). The main idea about how to design a solution to a real problem is identified as one of required skills in the 21st century (Lamb, Maire, & Doecke, 2017; Trilling & Fadel, 2009). Considering the importance of designing skills, it is interesting to incorporate design in the instrument.

Research Problem

Students' perception of new and renewable energy became our latent variable in this research. The measurement of a latent variable in educational settings is not usually easy to observe directly. Therefore, the construction of theory is needed to create scales and subscales to clarify the variable. This article aims to develop an instrument to measure students' perception of new and renewable energy (PINRE). Two research questions were posed:

1. How to develop scales, subscales and items to measure students' perception of new and renewable energy?
2. To what extend is PINRE considered as an applicable instrument for students?

Research Methodology

PINRE was designed with consideration of the most common and widely used new and renewable energy. Accordingly, general information about NRE, solar, wind and nuclear energy was chosen. Other sources of NRE (such as water, thermal, tides, etc.) were not developed as part of the construct because it is too complex or not suitable for the middle school student's context.

The middle and high school level was chosen because energy is integrated in their classroom but there is a lack of evidence on how they perceive the NRE issues. On the other hand, they will grow and become citizens shortly. Therefore, their perception of NRE is important to measure and strongly reflect on the future of energy issues. This study was conducted as research and development (R and D) design with adjusted steps from the engineering process (NGSS Lead States, 2013). This process is generally divided into three steps, which are define, develop and optimize solution, done cyclically to develop the final version of PINRE.

Participants

During the I and II phases, the contribution from experts, and four middle school students was valuable to form the initial version of PINRE. From their suggestions, the PINRE was ready to be used in field trial that engaged 229 high school students in three cities of Indonesia (Table 1). The sample comprised students from grades 9 and 12, from 7 state and private schools.

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Out of 229 participants, 152 were female and 77 were male students. The grades represented middle school students (MS) and high school students (HS). It is commonly believed that students' perception of NRE increases with grade. The student participants were given access to the instrument in 60 minutes during their science class. The whole test was supervised by their science teacher. After the test, 229 test papers were collected and sent to us to be analyzed.

Table 1. Distribution of participants

Cities	Grade 9	Grade 12	Total
Bandung	68	35	103
Surakarta	30	-	30
Cirebon	65	31	96

Procedures

The development of PINRE followed the scheme in Figure 1. This procedure consists of the following three sequences:

1. Phase I

The initial phase mainly consists in discussion about what is needed as content of PINRE. The concept of content validity is to what extent the content of PINRE is a representative sample of NRE concepts. It is established deductively, by defining a universe of items and sampling systematically within this universe to establish the test (Cronbach & Meehl, 1995).

For designing PINRE with good content validity, theoretical framework of NRE for middle and high school students was performed. The NRE concepts from physics and science curricula about new and renewable energy in the USA, Japan and Indonesia were considered as suitable knowledge and perception for middle and high school students. Based on the results of this process, scales, subscales and items were designed. The subscales derived from the essential part of each scale. Each subscale was expanded to be items. Items were developed by considering previously reported instruments (Jan DeWaters & Susan Powers, 2013; Kishore & Kisiel, 2013).

To measure content validity, discussions with three physics education lecturers, three PhD candidates in science education, two science teachers and one educational measurement expert were held. The reviewers were asked to consider five questions:

a) Are the items factually correct?
b) Are they fit with the scale?
c) Are they clear and not confusing?
d) Are they relevant with NRE?
e) Is the scoring in the rubrics suitable for the item?

Some items were modified after phase I due to some experts' suggestions.

2. Phase II

In developing PINRE, the issue of readability and easiness of use were considered. This issue is also well-known as face validity concept. Face validity is a subjective judgment of the operationalization of PINRE. The criterion for an instrument to have good face validity is whether its content simply looks relevant to the person taking the test. It evaluates the appearance of the questionnaire in terms of feasibility, readability, consistency of style and formatting, and clarity of the language used (Drost, 2011; Taherdoost, 2016).

The draft of PINRE from the first phase needed examination by language experts because this instrument has two versions, i.e., English and Indonesian. Since this instrument was designed for middle school and high school students, the early responses from 4 students were vital. The reviewers were asked to consider these three questions:

a) Are the items translated correctly?
b) Are they understandable?
c) Are the instructions clear?

3. Phase III

From Phases I and II, PINRE is subjectively validated by the experts and users. Moreover, more scientific and objective proof of validity is needed. The construct validity is an estimate variance in the measure that reflects variance in the underlying construct (Westen & Rosenthal, 2003). Among several statistical methods, Confirmatory Factor Analysis (CFA) gives better results in testing the validity of an instrument (Hamdan Said, Badru, & Shahid, 2011; Ugulu, 2013). Confirmatory factor analysis (CFA) was performed on data from 225 participants in order to confirm the factor structure that emerged in phases I and II, which allowed for correlation with each other. Based on Phases I and II, the scales and subscales of PINRE were set. This pilot of PINRE needs statistical tools to provide evidence that the number of scales and subscales is as expected. CFA will determine if different scales and items are fit for this research.

To conclude how well PINRE fits with the 229 trial data, several types of fit indicators are applied. Comparing with the best possible model, the fit indicators show how PINRE fits the trial data. In this research, the indicators of fit model from CFA were:

a) Chi square test model (χ^2), assessing overall fit between trial data and fitted covariance matrices. The cutoff P-value is greater than 0.05, which indicates a good fit.
b) Incremental fit index, commonly used is Comparative Fit Index (CFI). The cutoff values are greater than 0.90, which indicates a good fit.
c) Parsimony index, commonly used is Root Mean Square Error of Approximation (RMSEA). This index is a parsimony adjusted index. The cutoff values are smaller than 0.08. (Brown, 2006; Hooper, Coughlan, & Mullen, 2008; Kline, 2011).

All those indicators showed our PINRE is a suitable model. In addition to validity, reliability is another crucial parameter to determine the functionality of an instrument. Among the estimation of reliability, Cronbach's α is one of the methods to estimate reliability based on internal consistency. The Cronbach α coefficient depends on the correlation among items, items number and variance among the scores. The reliability cutoff value depends on the urgency and purpose of the instrument, 0.7 is commonly accepted (Cortina, 1993; Murphy & Davidshofer, 2005).

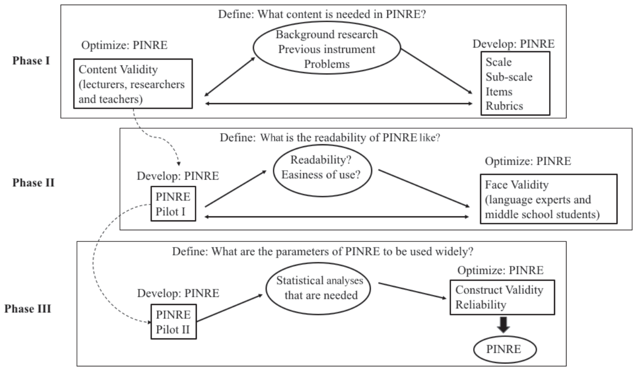

Figure 1. Scheme of PINRE Development Process

Data Analysis

The qualitative data (Phases I and II) were analyzed based on the need of each phase. Every suggestion from the experts was triangulated to create the blueprint of PINRE. Quantitative data were analyzed in Phase III. A total of 229 sets of data were received from the instrument, but only those with complete responses (225) were analyzed. These complete sets were assessed based on the rubrics with scoring from 0–4. Descriptive statistics and reliability analyses were performed with the support of statistical analysis software R packages. Moreover, the CFA was used to estimate how well the instrument fits. It was run in second order CFA in statistical analysis software Lisrel 8.50.

Results and Discussion

Phase I

The issue of validity in educational measurement mainly depends on proper conceptualization and how to operate the concepts (Slawomir Pasikowski, 2018). As the beginning of the whole development process, this phase is crucial to set the conceptualization of PINRE (Figure 2). The construct of PINRE, which has four main scales, was agreed on by all the experts, considering that general information about NRE is needed and solar, wind and nuclear are the most common sources of energy in middle school and high school. From the scales, 10 subscales were designed and expanded into 12 items.

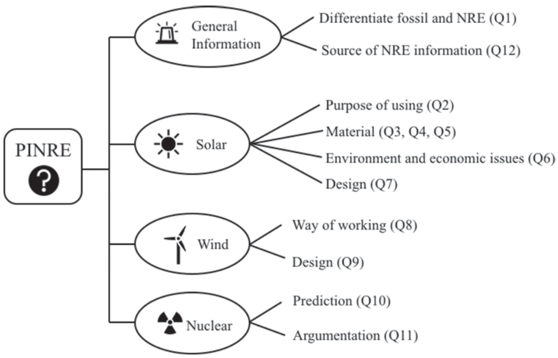

Figure 2. Framework of PINRE

The initial draft of PINRE was discussed by the experts. From the discussion, some items were revised, e.g., in the nuclear scale, subscale prediction, item Q10, shown in Table 2. In line with the item changes, the rubrics for PINRE were adjusted during this phase. The rubrics main adjustment in the scoring system was the clearness of indicators in each scoring. While at the beginning, the rubrics did not have zero as a score, they had 1–4 as scores. The reviewers suggested that zero score is needed. The main considerations were the possibility of not answering some questions at all and the 9t□-grade students possible lack of familiarity with some questions such as the process of making solar panels (Q3).

Table 2. Item revision in PINRE nuclear scale (Q10)

Item	Statement or Question
Initial	What will happen if a nuclear power plant is built in your town?
Revised	If a nuclear power plant is built near your hometown, predict what will happen to electricity supply and the environment.

Phase II

The outcome of Phase I is called PINRE Pilot I, which is provided in two languages (English and Indonesian). For analyzing the readability and easiness of use, two language experts and four middle and high school students were asked to give their opinions. This process made sure that PINRE had good face validity. According to the reviewers' opinions, some words were difficult to understand, thus non-renewable energy was changed to fossil energy. In some questions (Q7 and Q9) that require some designing, some additional instructions were needed such as draw your design here and explain your design.

Phase III

In the final phase, PINRE Pilot II (result of Phase II) had a trial stage with 229 student participants. The descriptive statistic and statistical parameters estimation of this instrument were made. Figure 3 shows a brief description of the participants, who came from two high schools and five middle schools, based on gender differentiation.

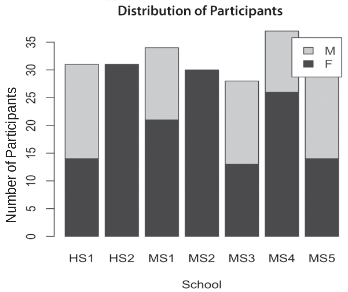

Figure 3. Descriptive statistics of participants

The construct validity was investigated using CFA, supported by Lisrel 8.50 software. By design, we have a construct that consists of four scales, which are general information (GI), Solar power (Solar), Wind power (Wind) and Nuclear power (Nuclear). These scales were expanded into 12 items. CFA was performed to determine how well the data fit with the scales and items in Figure 2. The results of CFA are presented in Figure 4.

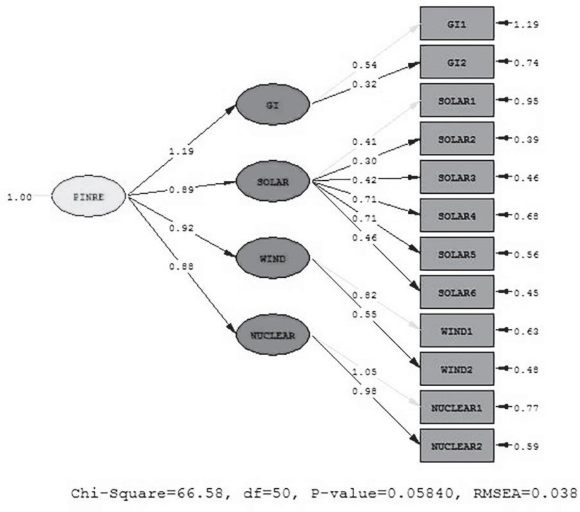

Figure 4. Construct validity of PINRE

As can be seen, the important parameters from CFA results (Figure 4 and Table 2) are $\chi^2 = 66.58$, P-value = 0.058, RMSEA=0.038, CFI = 0.98. Since $\chi^2 = 66.58$, P-value = 0.058, there are non-significant differences between the proposed framework in Figure 2 with the data. Other indicators, i.e. the values of CFI and RMSEA, are within the cut off values. The result indicates that the model is fit for four factors solution, which has a positive result. In other words, as a latent variable, PINRE can be defined by four scales from our initial design.

Table 3. Goodness of fit statistics

Indicators	Value
Degrees of Freedom	50
Minimum Fit Function Chi-Square	65.12 (P = 0.074)
Root Mean Square Error of Approximation (RMSEA)	0.038
Comparative Fit Index (CFI)	0.98
Root Mean Square Residual (RMR)	0.040
Standardized RMR (SRMR)	0.043

As for reliability analysis (Table 4), even though the cutoff for reliability varies depending on the theoretical aspect and purpose of the instrument, our Raw and Standardized α for PINRE is 0.72, which is categorized as a reliable instrument. With our Raw and Standardized α score, this instrument showed consistency in measuring PINRE.

Table 4. Reliability result of PINRE

Raw α	Std α	G6(smc)	Average_r	S/N	Ase	Mean	Sd	Median_r
0.72	0.72	0.75	0.18	2.6	0.027	1.5	0.44	0.17

Conclusions

The development of PINRE demonstrated a systematic and cyclical process for instrument construction. The processes from all the three phases produced a more digestible version of PINRE, but still standardized. The final version of PINRE consists of four scales, which are general information about NRE, solar, wind and nuclear with 12 subscales that have excellent fit based on different fit indicators (χ^2, P-value, RMSEA and CFI). Our Cronbach α indicates that this instrument is reliable.

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