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Validity and Reliability of Conceptual Survey in Electricity and Magnetism (CSEM) Instrument in Malay

Mohd Ariff Ab Ghani, Shahrul Kadri Ayop
Department of Physics, Faculty of Science and Mathematics, Universiti Pendidikan Sultan Idris, Malaysia

Abstract: Electricity and magnetism is among the most challenging topics in physics course. Conceptual Survey in Electricity and Magnetism (CSEM) has been developed to probe students understanding on these topics at pre-university and early undergraduate level. However the instrument is not yet available in Malay version. The aim of this study was to validate and to get the reliability of the adapted CSEM, so called CSEMy. The adaptation of the CSEMy followed three phases: Phase 1 Pre-adaptation, Phase 2 Translation and Phase 3 Reliability. The study successfully produced validated and reliable CSEMy. The result of using CSEMy is valuable for standardized comparison among international institutions as the language difficulty was removed to focus more on probing the conceptual understanding.

Keywords: Misconceptions, Instrument Translation, CSEMy

Introduction

For the past three decades, the study of misconceptions becomes a central issues in science education (Turgut, Gurbuz, & Turgut, 2011). Many studies have been conducted to identify the level of understanding and misconception. Misconception that exist among students is believed to originate from experiences of their daily life (Planinic, 2006). Many techniques have been used in determining the conceptual understanding and misconception among students. Multiple-choice question (MCQ) is one of the common techniques chosen by researchers in identifying student's misconceptions. MCQ also can be used to evaluate students' content knowledge in a topic (Damanhuri, Treagust, Won, & Chandrasegaran, 2016).

In physics course, electricity and magnetism are among the most challenging topics. In assessing student knowledge of electricity and magnetism, the Conceptual Survey of Electricity and Magnetism (CSEM) have been developed. The survey in the form of MCQ test covered many different concept areas in electricity and magnetism. CSEM was mapped on 6 different but related conceptual areas using 32 multiple-choice questions (Maloney, O'Kuma, Hieggelke, & Van Heuvelen, 2001). The purpose of this study is to translate CSEM's original instrument in English into Malay language. Translation of CSEM instrument into Malay language is required for its relevant use within Malaysian context. This adapted instrument is called as the Conceptual Survey of Electricity and Magnetism in Malay (CSEMy), with just an additional "y" at the end of CSEM. Such cultural and language translation has been performed on a similar knowledge probe known as Force Concept Inventory (FCI) for Malaysian High School students (Ismail & Ayop, 2016).

Starting year 2010, Malaysian government has implemented a policy so called *Dasar Memartabatkan Bahasa Malaysia Memperkukuh Bahasa Inggeris* (MBMMBI) to uphold the Malay language and to strengthen English language in teaching Science and Mathematics using Malay language in national school as a medium of instruction. Due to the change in Malaysian education policy, researchers and educators need a validated instrument which can be reliably used to assess student knowledge in a certain topic and fit with the current education scenario in the country. The major objective of this study was to adapt CSEM via major translation process that can be used to probing knowledge of pre-university students in Malaysia in the mentioned topics.

Even though mhas been introduced in Malaysia schools, English remains the medium of instruction in teaching Science and Mathematics at pre-university level. In the national examination the question papers are prepared in bilingual version English and Malay language. Therefore in adapting the CSEMy, the questions of instrument were also prepared in bilingual version with the similar type setting format to the real national examination.

The adapted instrument, CSEMy was integrated with six-point scale of Certainty Response of Index (CRI) for the purpose of misconception analysis. Respondent is requested to provide the degree of certainty to justify their own ability to select and utilize well-established knowledge, concepts or laws. The combination of a test with CRI will help educators to identify misconception among subjects (Hasan, Bagayoko, & Kelley, 1999).

Methodology

The adaptation process involved three phases as illustrated in Figure 1. Phase 1 is Pre-adaptation starting with the adaptation permission from the administrator of the instrument. CSEM is administered by the PhysPort team, (https://www.physport.org). PhysPort is a web-based portal, which supports physics teaching with research-based resources. Once the permission was obtained, the adaptation process began.

The six-concept areas in CSEM were content-mapped to Malaysian pre-university specification syllabi, which were Malaysian Higher School Certificate (STPM) and Matriculation Program, both are controlled under Malaysia Ministry of Education. Two experts were asked to validate the mapping (Validation I). This process is important to make sure that CSEM is relevant to Malaysian pre-university population.

In Phase 2, which is Translation phase, the CSEM was forward-translated from English to Malay by English-Malay bilingual translation expert. Forward-translation-only possess weakness in the absence of equivalency verification (Maneesriwongul & Dixon, 2004). In the cross cultural research the most important element is to produce the equivalency between items in the source language and the targeted language based on its content (Brislin, 1970). However, this was overcome by translation validation (Validation II) by two field experts, who were involved in physics education. Experts in Validation I are not the same person as in Validation II. All experts are bilinguals and competent in both English and Malay. A bilingual person refer to person who is able to speak the original and target languages equally well and who is sufficiently educated to have familiarity with the concepts and the relatively formal language presented in the record forms (Chen & Boore, 2010). The validation involved verification of instrument format, language style and scientific terms. Experts were asked to rate each question using four-point scale, the lowest scale 1 for the most irrelevant and the highest scale 4 for the most relevant question (McKenna & Doward, 2005). Before adapted CSEM draft was given to the experts, it was set into the proper bilingual instrument with improvement in format such as figure amendment.

Finally, the adapted CSEM was tested to find its reliability via item analysis (difficulties index and point-biserial correlation coefficient). For that purpose, the instrument was administered to 60 students of pre-university college located in Pahang, Malaysia. Difficulties index is a measure of how difficult an item is and calculated by finding the percentage of subject answered a question correctly (Maloney et al., 2001). Difficulties index of i^{th} question is

$$P_i = \frac{N_c}{N}$$

where N_c is the number of students answer correctly and N is the number of students answer the question.

It is natural to calculate the average difficulty of questions in a group of the same concept area (Maja Planinic, 2006). Therefore, the average difficulties index for a group of questions is

$$\bar{P} = \sum_i^n \frac{P_i}{n}$$

where P_i is the individual index of questions in the group and n is the number of item in the concept of area of the group.

The point-biserial correlation coefficient is a measure of individual item reliability. It is defined as the correlation between the item scores and total scores. The coefficient for i^{th} question is

$$r_{pb,i} = \frac{\overline{X} - \bar{X}_0}{\sigma_x}\sqrt{P_i(1 - P_i)}$$

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where $\bar{X}$ is the average of total score obtained by those who correctly answer the question, $\bar{X}_0$ is the average of total score obtained by those who incorrectly answer the question, s_X is the standard deviation of the total score and P_i is the difficulty index for the question.

Similar to the difficulties index, the evaluation of a group of question in the same concept area is justified by the average point-biserial correlation coefficient

$$\bar{r}_{pb} = \sum_{i}^{n} \frac{r_{pb,i}}{n}$$

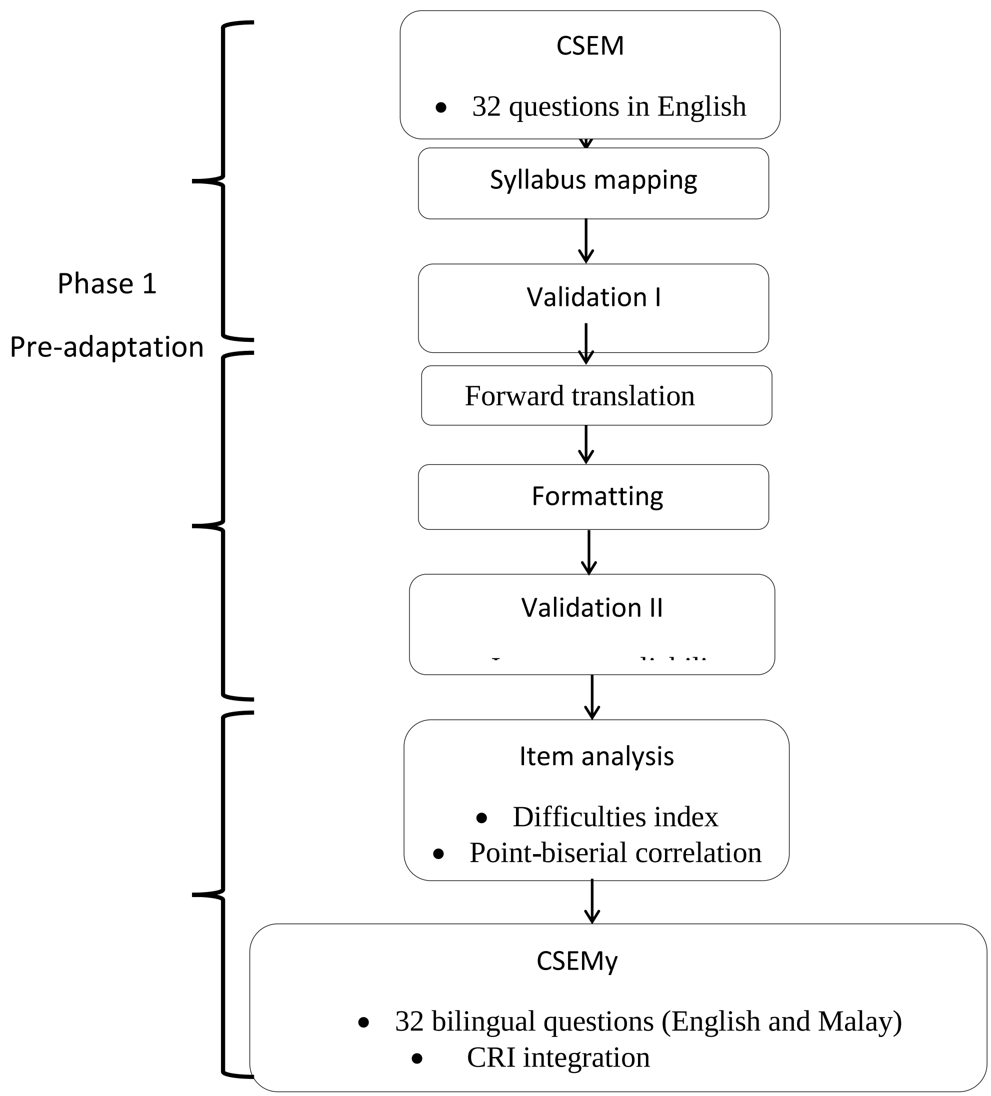
where is the point-biserial coefficient for each item and *n* is the number of item in concept of area.

At the end of the adaption process, the validated and reliable instrument called CSEMy was produced.

Figure 1: The process of CSEM adaptation to produce CSEMy

Result

A.



Phase 1: Syllabus mapping

Table 1 shows the mapping concept areas in CSEM to learning outcomes in Malaysian pre-university syllabi. In CSEM, there are six concept of areas coded as ECF, EFF, EPE, MFF EMI and NLE that covers three main topic (electrostatics, magnetic fields and electromagnetic induction) in electricity and magnetism in Malaysian pre-university syllabi.

Table 1: CSEM concept mapping Malaysian pre-university syllabi.

Concept area	Number of question	Question number	Learning outcome (Student should be able to….)
Electric charge and force (ECF)	6	1-3,5,6 and 8	State and use Coulomb's law Sketch electric force diagram
Electric field and force (EFF)	5	9 and 12-15	Define electric field strength Sketch the field pattern
Electric potential and energy (EPE)	6	11 and 16-20	Define electric potential Explain the meaning equipotential surfaces
Magnetic field and force (MFF)	6	21-23, 25, 26 and 28	Define and use concept of magnetic field, force on moving charge, force on a current-carrying conductors, magnetic field due to current, force between two current-carrying conductors
Electromagnetic induction (EMI)	4	29-32	State and use Faraday's law and Lenz's law Explain the phenomenon of self-induction
Newton's Law in electromagnetic (NLE)	5	4, 7, 10, 24 and 27	Interaction of the forces Motion of charged particles in uniform electric and magnetic field.

B. Phase 1: Validation 1

At the end of Phase 1, both experts agreed on item mapping of CSEM concept areas to the Malaysian syllabi (Table 1) with several example comments to address as shown in Table 2.

Table 2: Content validation for CSEM instrument

Concept area	Experts example comments	Researcher response
ECF	Focusing on Coulomb's law and not focusing on distributions of charge Apply graphical method for vector addition	Distributions of charge in inductor and insulator is a basic concept in electricity

Table 2 (continue)

EFF	Focusing on point charge only and not for body of charge The electric field is not come from a point charge	The given diagram is not suitable for electric field coming from a point charge and certain modification was be made
EPE	A good conceptual question for electric potential. Student should be able to sketch and used certain formula to get the answer.	Some diagrams are redrawn to clarify the question
MFF	Deep understanding for magnetic field and force	Some diagrams are redrawn to clarify the question.
EMI	The number of question not too much cover the topic.	There are link of a different conceptual in the same question
NLE	Combinations of Newton's law question is good for student to relate the topic of mechanic in electricity and magnetism.	By understanding the Newton's law make it easier to probe some concept in electricity and magnetism.

C. Phase 2 : Formatting

Before the translated draft was given to experts for Validation II, the instrument was compiled and formatted according to the Malaysian Examination standard. Clarity on figures and formatting were improved. Table 3 lists example of formatting and figure amendment. Figure 2(a) and Figure 3(a) are the original figure. Figure 2(b) and Figure 3(b) are the improved version.

Table 3: CSEMy first draft adaptation

Modification	Number of question	Description
Formatting	20	Change the answer format
	23	Standardize the use of symbol for current.
	26	Change the positions notation from A and B to P and Q
Figure amendment	32	Redraw and rearrange the figure

Figure 2(a): Original diagram in question 20	Figure 2(b): Amendment diagram in question 20

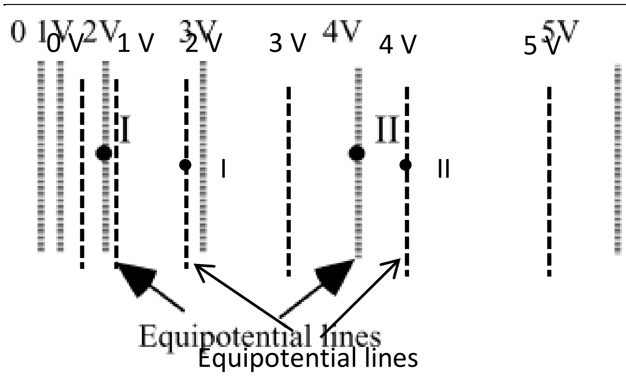
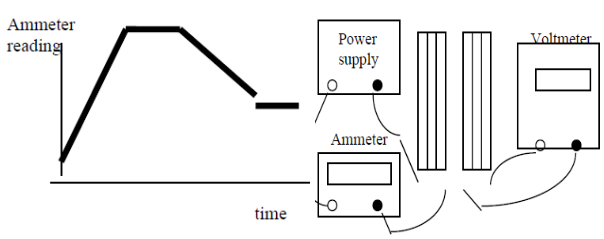
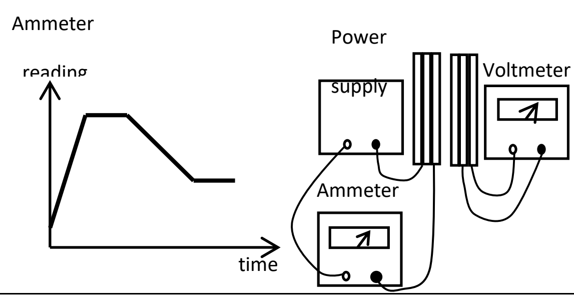


Figure 3(a): Original diagram in question 32	Figure 3(b): Amendment diagram in question 32





D. Phase 2 :Validation 2

Table 4 tabulated scores rated by two experts on each question. Data from Table 4 is transformed into Table 5 to calculate inter-rater score. It was found that the score is 1.0 (Davis, 1992).

Table 4: Inter-rater reliability for CSEMy instrument

Concept area (Question number)	Expert 1	Expert 2
ECF (1, 2, 3, 5, 6 and 8)	3,2,4,4,4,3	4,2,4,4,4,4
EFF (9, 12, 13, 14, 15)	3,3,4,4,4	4,3,4,4,4
EPE (11, 16, 17, 18, 19, 20)	4,3,3,3,3,3	4,3,3,3,3,4
MFF (21, 22, 23, 25, 26, 28)	4,3,4,4,4,3	4,4,4,4,4,4
EMI (29, 30, 31, 32)	4,4,3,4	4,4,4,4
NLE (4, 7, 10, 24, 27)	4,3,3,4,3	4,3,4,4,4

Table 5; Inter-rater score calculation.

		Rater 1 score		
		1 or 2	3 or 4	Total
Rater 2 score	1 or 2	1	0	1
	3 or 4	0	31	31
	Total	1	31	32

* Adapted from Davis (Davis, 1992)

Thus,

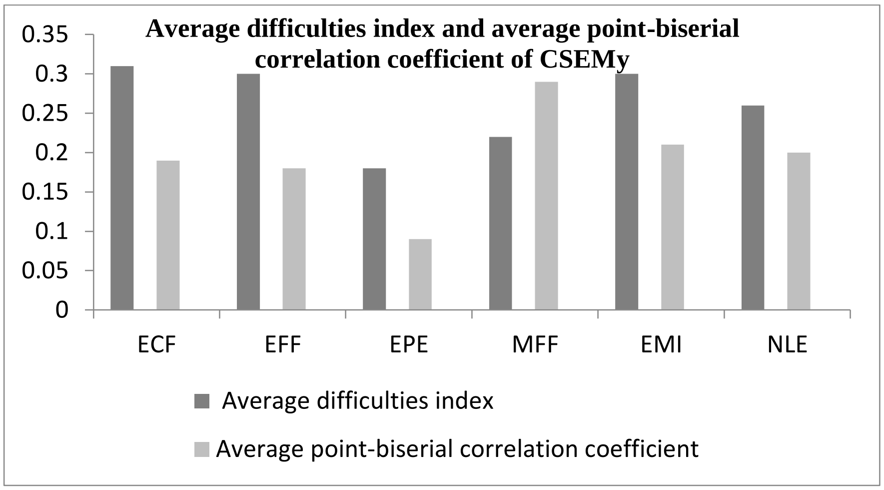
$$\text{Inter-rater agreement} = \frac{1+31}{32} = 1$$

E. Phase 3 : Reliability

The standard measurements of quality of a test items in CSEMy is illustrated in Figure 4. The item quality was justified by average difficulties index, $\overline{P}$ and average point-biserial correlation coefficient, $\overline{r}_{pb}$. Maximum values of both indicators are 1.0.

Figure 4: Average difficulties index ($\overline{P}$) and average point-biserial correlation coefficient ($\overline{r}_{pb}$)

of CSEMy



Discussion

In Phase 1, the syllabus mapping was carried out identify the equivalency and concept coverage between learning outcome in Malaysia pre-university syllabi specification with concept of area in CSEM. This is important to make sure the CSEM is relevant as a whole to probe Malaysian's student understanding for international standardized comparison. From the syllabus mapping process, the questions in CSEM suit to the Malaysian pre-university syllabi specifications as tabulated in Table 1 even though the arrangement of questions is not in order. The mapping was validated by two experts who were involved in pre-university physics teaching in Validation I (Table 2). This shows that the CSEM is suitable to probe Malaysian pre-university students' understanding in Electricity and Magnetism.

In Phase 2, CSEM was translated from source language (English) to targeted language (Malay). Once completed, both English and Malay version were combined to produce a bilingual CSEMy draft. CRI component was also integrated in the answer sheet.

Based on the experts comment in Validation I, CSEMy underwent adaptation process with some amendments to some questions. For example, question 20 was improved in answer format meanwhile question 23 underwent minor change in symbol notation. For question 26, the notation of position was improved. All questions format and style were standardized. Some diagrams have been redrawn since the original diagram was less clear and ambiguous.

The CSEMy draft was then given to two bilingual and field experts for Validation II. Both works independently. In this process, the expert played active role. They were not only verified questions, but also suggested overall improvement such as in language style and terms, figure improvements and formatting. This was to make sure the adaptation met the equivalence meaning and physics terminology. The obtained validation score was 1.0. This indicated that CSEMy can serve its purpose correctly.

In Phase 3, the CSEMy reliability was evaluated through item analysis. The concept area tested in CSEMy showed a range of average difficulties index between 0.2 to 0.3 (Figure 4). Based on those results, the tested concept areas in CSEMy were in moderate range (0.21-0.8) and were considered acceptable (Ding & Beichner, 2009). The $\overline{r}_{pb}$ for concept of area in CSEMy resulted in a range between 0.1 and 0.3 (Figure 4). A satisfactory point-biserial correlation coefficient is $\overline{r}_{pb} \geq 0.2$ (Ding & Beichner, 2009), $\overline{r}_{pb}$ for the all concept of area was greater and equal to 0.2 except for EPE, which showed a lowest $\overline{r}_{pb}$ of 0.1. However, none of the questions were excluded since the purpose of the instrument was not to discriminate students based on their understanding but to detect any concept difficulty and misconception with the help of CRI. Low $\overline{r}_{pb}$ was expected since the questions were very good in probing students understanding difficulties and the student population as whole faces those difficulties. Thus the CSEMy has a good reliability in that sense.

Conclusion

A valid and reliable CSEMy was produced. CSEMy contains bilingual questions in English and Malay with integrated CRI. CSEM instrument underwent twice content validation in Phase 1 Pre-adaption and Phase 2 Translation. CSEM shows good reliability through item analysis. Hopefully CSEMy becomes useable to researchers and educator as guidance to probe the understanding level and misconception in electricity and magnetism among students especially at pre-university level in Malaysia.

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*To protect the integrity of the CSEMy (Appendix), the answer key can be obtained only by educators registered and verified by PhysPort portal.

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