Systematic review of physic laboratory skills assessment instruments based on PhysPort with Nvivo

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Abstract. To help educators and researchers related to the availability of standardized physics laboratory skills assessment instruments, so this article is here to present systematically review various physical laboratory skills assessment instruments to provide information and their needs for various forms of physics laboratory skills assessment instruments. This study was conducted with a systematic review method, through identification, evaluation and interpretation of Physics-based database laboratory physics assessment instruments using Nvivo version 12 plus. A systematic review was carried out on the themes informed by PhysPort, including the instrument’s name, developer, purpose, format, duration, focus and level of instrument’s use. The results of systematic reviews report the results of synthesis, so that similarities and between instruments are found. The review results show that there are similarities and differences in aspects of the purposes, format, duration, focus and level of use.

1. Introduction

Research-based assessment instruments had a major impact on physic education reform by providing universal and convincing measures of student understanding that educators can use to assess and improve the effectiveness of their teaching. Furthermore, the use of research-based assessment instruments has potential impact to change the teaching practices of educators [1]. Researches that use research-based instruments consistently show that research-based teaching methods can significantly enhance students' conceptual understanding of physics [2]. In the context of students, the use of research-based assessment instruments can help inform students how well they are (that is, their strengths and weaknesses), what they may still need to learn, and can motivate students for greater efforts.

Research-based assessment instruments have been produced by physic education researchers [3-7]. These instruments are produced and tested rigorously with carefully crafted questions to investigate students' everyday ideas related to how the world works, their attitudes and beliefs about science and other actions [8]. One of the website where physics education researchers publish research-based assessment instruments is PhysPort. PhysPort previously called "The PER User's Guide" is a website for educators and researchers in physics education about research-based teaching and assessment [9]. The website was developed by The American Association of Physics Teachers in collaboration with Kansas State University and supported by the National Science Foundation. In Physport, educators and physics education researchers can learn about research-based assessments in physics and related fields, including content and non-content topics such as attitudes, beliefs and scientific reasoning, for various levels from the secondary school level to postgraduate level [10].
Because of the great potential of the use of research-based assessment instruments in order to enhance teaching, inform strengths and weaknesses and motivate students, this article specifically focuses on systematic reviews of research-based assessment instruments. This article presents an overview of the PhysPort website based Physics laboratory skills assessment instrument. The selection of these instruments was reviewed with the consideration that laboratory skills are important skills should be trained and assessed in teaching physics. To be able to assess these skills, a good assessment instrument is needed. For this reason, it is deemed necessary to know and understand the characteristics of these instruments.

2. Methods
The study was conducted using a systematic review method \([11]\). Through this method, identification was carried out, evaluation and interpretation of the Physics database-based physics laboratory skills assessment instrument is carried out using Nvivo version 12 plus \([12-13]\). The Systematic Review stage is carried out as shown in Figure 1.

![Systematic review stages](image)

**Figure 1.** Systematic review stages

Data sources for this systematic review are instruments for assessing physics laboratory skills that found on PhysPort \([14]\). PhysPort contains many resources (expert recommendations, teaching, assessment and workshops) for educators and researchers in physics education \([15]\), as see as Figure 2.

![All instrument content available on PhysPort](image)

(a) All instrument content available on PhysPort; (b) Instrument of laboratory skills

In the PhysPort assessment, physics educators and researchers can access 79 research-based assessment instruments, equipped with information on education level categories, focus, format, validation techniques and language that can be filtered out by educators and researchers as needed (Figure 2 (a)). Reviewed from the aspect of the focus of assessment, PhysPort provides several assessment instruments including knowledge of physics content, problem solving, scientific reasoning, laboratory skills, beliefs / attitudes and interactive teaching. This systematic review, only carried out on instruments that focus on the assessment of physics laboratory skills (Figure 2 (b)).
A systematic review of the themes informed by PhysPort, including the name of the instrument, developer, level of validation, purpose, format, duration, focus and level as shown in Figure 3. The results of a systematic review would report the results of the synthesis, so it could be found similarities, differences and gaps between instruments.

3. Result and Discussion

Based on the results of the PhysPort database search, five instruments were assessed for physics laboratory skills, as shown in Table 1.

| Instrument                                | The Developer                                           | Research Validation     |
|-------------------------------------------|---------------------------------------------------------|-------------------------|
| Physics Measurement Questionnaire (PMQ)   | Saalih Allie, Andy Buffler, Loveness Kaunda, Bob Campbell, and Fred Lubben | Silver Validation       |
| Physics Lab Inventory of Critical Thinking (PLIC) | N.G. Holmes, C.E. Weiman, K.N. Quinn, C.J. Walsh & the Cornell Physics Education Research Lab | Silver Validation       |
| Concise Data Processing Assessment (CDPA) | James Day and Doug Bonn                                 | Silver Validation       |
| Data Handling Diagnostic (DHD)            | Galloway, R. K., Bates, S. P., Maynard-Casely, H. E., & Slaughter, K. A. | Silver Validation       |
| Measurement Uncertainty Quiz (MUQ)        | Duane Deardorff and Robert Beichner                    | Bronze Validation       |

Table 1 show that five of physics laboratory skills assessment instruments were developed based on research in the category of four silver and one bronze instruments. The silver category is the second level of research validation, covering five categories of validation, namely validation based on research on students, conducted through interviews, at various institutions, by several research groups and publications reviewed together. While the Bronze category research validation is the third level of research validation, which includes three categories of validation, namely validation is based on research on students, through expert judgment and interviews [14].
Next, the researcher will represent in graphic form about results of a systematic review through a coding project map to explore and present the data connection as shown in Figure 4.

Figure 4. Project map purpose, format, duration of tests, focus of the test and level of use the laboratory skills assessment instrument

Figure 4 provides information that there are at least four purposes of the five laboratory skills instruments reviewed, there are namely assessing student abilities of handling data, assessing student abilities of uncertainty data, assessing student abilities of measurement and assessing student critically evaluating methods, data and models; presented in pre-post, multiple-choice, short answer, multiple response, and agree-disagree formats; duration of instrument completion is no more than 30 minutes; the focus of the instrument is testing accuracy & precision, quantitative error analysis, evaluating data fit, generating & evaluating conclusions, uncertainty in measurement, designing & evaluating experiment models and relationships between functions graphics and number; and orientation of the use of the instrument is projected for graduate, high school, upper-level, intermediate and intro college students.

If data connection result of coding from the five instruments based on five themes have been reviewed, then explored and represented graphically through the project map, a graphical representation would be obtained as shown in Figure 5. Figure 5, itself, shows the similarities and differences in purposes, format, duration, focus and level of use five laboratory skills instruments of physics. If that observed from the purposes, the Physics Measurement Questionnaire (PMQ) and Concise Data Processing Assessment (CDPA) have the same goal, namely assessing student abilities of measurement; Physics Measurement Questionnaire (PMQ), Concise Data Processing Assessment (CDPA) and Measurement Uncertainty Quiz (MUQ) have a common goal of assessing student abilities of uncertainty data; Concise Data Processing Assessment (CDPA) has a common goal with Data Handling Diagnostic (DHD), namely assessing student of handling data. Whereas the Physics Lab Inventory of Critical
Thinking (PLIC) has its own purposes compared to the other four instruments, namely assessing student critically evaluating methods, data and models [3-7,14].

In terms of the instrument format, Physics Measurement Questionnaire (PMQ) is presented in a different format than the other four instruments, namely short-answer. The Physics Lab Inventory of Critical Thinking (PLIC) is an instrument presented in four formats including pre-post, multiple-choice, agree-disagree, and multiple-response. Three other instruments, Concise Data Processing Assessment (CDPA), Data Handling Diagnostic (DHD) and Measurement Uncertainty Quiz (MUQ) are presented in the same two formats, namely pre-post and multiple-choice [3-7,14].

![Diagram showing similarities and differences in purpose, format, duration of tests, focus of the test and level of use the laboratory skills assessment instrument](image)

**Figure 5.** Project map of similarities and differences in purpose, format, duration of tests, focus of the test and level of use the laboratory skills assessment instrument

In general, the five instruments take not more than 30 minutes. Physics Measurement Questionnaire (PMQ) and Concise Data Processing Assessment (CDPA) allocate the same time to complete the instrument for 30 minutes, Measurement Uncertainty Quiz (MUQ) and Physics Lab Inventory of Critical Thinking (PLIC) successively allocate processing time for 15 minutes and 20 minutes. Whereas for Data Handling Diagnostics (DHD) the researcher did not obtain information regarding the duration of working time for the instrument [3-7,14].

Laboratory skills reviewed on the instrument, focuses on eight laboratory skills, which the Physics Measurement Questionnaire (PMQ) has a focus on studying laboratory skills related to data collection, data processing, and data comparison; The Physics Lab Inventory of Critical Thinking (PLIC) has a focus of more study than other instruments, namely uncertainty in measurement, evaluating data fit, designing & evaluating experimental models, and generating & evaluating conclusions. PLIC has the
same focus of study with CDPA, which is related to uncertainty in measurement. CDPA and DHD have similarities in the focus of the study of laboratory skills studied, namely the relationship between graphic and number functions. While DHD and MUQ have similarities in the focus of the study of laboratory skills studied, namely accuracy & precision and quantitative error analysis [3-7,14].

Level of instrument use, in terms of testing laboratory skills, where are the five instruments has a similarity in the level of use, which is intended for intro colleges. The Physics Lab Inventory of Critical Thinking (PLIC) is an instrument whose use is oriented at four levels, high-school, upper-level, intermediate and intro-college. PLIC has similarities with CDPA in terms of levels of use, namely for the upper-level, intermediate and intro college levels. Both are only different at one level, namely PLIC can be used for high-school level, while CDPA for graduate level. DHD, PLIC and CDPA have the same orientation in terms of the level of use for the intermediate level. Only MUQ is used for only one level, namely intro college [3-7,14].

4. Conclusion
PhysPort is a web site that can support the needs of instruments for assessing knowledge of physical content, problem solving, scientific reasoning, laboratory skills, beliefs / attitudes and research-based interactive teaching. Of the seventy nine research-based assessment instruments available at PhysPort, there are five research-based physics laboratory skills assessment instruments. The five instruments were developed through validation based on research on students' thinking, using a variety of methods (expert reviews, interviews and appropriate statistical analysis) and carried out at various levels, several research groups and shared publications.

The five physic laboratory skills assessment instruments were developed for the purpose of assessing the ability of students from secondary to graduate level related to the abilities of handling data, uncertainty data, measurement, evaluating methods, data and models with a shared focus on accuracy & precision, quantitative error analysis, evaluating data fit, generating & evaluating conclusions, uncertainty in measurement, designing & evaluating experimental models and relationships between graphics and number functions. In format, the instruments are presented in five formats including pre-post, multiple-choice, agree-disagree, short answer and multiple response with an instrument duration of not more than 30 minutes.

5. References
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