Work In Progress: Analysis of Reliability of The Fluid Mechanics Concept Inventory

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Abstract - A Fluid Mechanics Concept Inventory (FMCI) has been developed via a cooperative effort between faculty at the University of Wisconsin-Madison and the University of Illinois, Champaign-Urbana. This concept inventory has been developed to assess student understanding of undergraduate fluid mechanics as taught in mechanical engineering. Now in the third version, the FMCI has been tested in pre-course and post-course assessment. As a result of this testing, the reliability of the inventory is being evaluated through item examination of specific questions included on the FMCI.

Index Terms – Concept Inventories, Fluid Mechanics, Assessment, Reliability

INTRODUCTION

Commencing in 2001, a group of faculty from the University of Illinois Champaign-Urbana and the University of Wisconsin-Madison began the development of a concept inventory to be used in undergraduate courses in fluid mechanics in Mechanical Engineering. The concept inventory itself was developed to produce the same kind of information about student learning available to instructors that is obtainable from the Force Concept Inventory [1-2]. This activity is part of a larger effort under the support of the Foundation Coalition for the development of concept inventories in engineering [3].

The process used to produce the Fluid Mechanics Concept Inventory or FMCI was reported on at a previous FIE Conference [4]. As described, the FMCI consists of 27 questions that evaluate approximately 10 basic concepts.

More recently, a series of actions have been made to investigate the validity and reliability of the instrument itself. To do this, the FMCI was administered in four different classes in fluid mechanics at the University of Wisconsin-Madison. In addition, the FMCI was taken by the students at the beginning of the semester when they had just started fluid mechanics, and at the conclusion of the semester. In sum, students took the FMCI approximately 400 times, with about 200 students involved.

Once the initial phase of development of the FMCI was completed, and we began to have sufficient numbers of students that have produced scores on the FMCI, our focus has turned to evaluation of how good the FMCI was in determining student understanding of fluid mechanics, as expressed by student performance on the FMCI.

CONCEPT INVENTORY RELIABILITY AND VALIDITY

According to Wells and Wollack [5], “Test reliability refers to the consistency of scores students would achieve on alternate forms of the same test.” This is particularly important for standardized assessment instruments such as the concept inventories because the objective of the concept inventories is to provide an unambiguous measure of student understanding of a given subject or topic.

Another interpretation of reliability is that the “reliability provides a measure of the extent to which an examinee’s score reflects random measurement error.” For evaluating the reliability of the FMCI, our concern is with measurement errors that are “test-specific factors such as the specific set of questions selected for a test…” [5]

Achieving concept inventory reliability is a necessary step to achieving concept inventory validity. Here validity is a means of defining “the extent to which the inferences made from a test … is justified and accurate. Ultimately, validity is the psychometric property about which we are most concerned.” In other words, if a concept inventory is not reliable, then there is no need to determine if the inventory demonstrates validity. [5]

EVALUATION OF THE RELIABILITY OF THE FMCI

As has been described, the FMCI has been administered to students in a number of fluid mechanics classes, and with the assistance of the Testing and Evaluation Services of the University of Wisconsin-Madison, each of the questions has been analyzed for discrimination. This is being done primarily through the point-biserial correlation ($r_{pb}$), a statistical quantity indicating the correlation between subjects’ answers on a particular question and the subjects’ overall score on the concept inventory. A large positive $r_{pb}$ for the correct answer shows that the subjects taking the concept inventory with high overall scores did well on an individual question on the concept inventory. Conversely, a low or a negative value for the correct answer means that a particular question will reduce reliability of the concept inventory.

As an example, the first question on the FMCI is presented in Figure 1 below. According to the results of the
statistical analysis, this question seems to be a good one. First, as shown in Table 1, the probability of a correct response was 0.56 averaged over the three classes that were involved in this sample. Further, as illustrated, all of the answers were selected, with the most common error being selection of Answer A. The $r_{pbi}$ for the correct answer is 0.33, which is considered to be good value. In contrast, all of the other answers have a negative value of the $r_{pbi}$ indicating that the wrong answers are serving as acceptable distracters.

Overall student performance on the FMCI was divided into quintiles and then correlated with the results on each individual question. As illustrated in Figure 2, for Question 1 there is a consistent trend between the answers given by a student and the quintile to which each student belonged. For this question, overall student performance on the FMCI had a nearly direct correlation with the probability of a correct selection of the answer.

1. A fluid flows through a pipe with a uniform cross section area. The density of the fluid decreases to half its initial value as it flows through the pipe. Circle the letter of the correct statement.

| A | $V_1 = 2V_2$ |
| B | $2V_1 = V_2$ |
| C | $V_1 = V_2$ |
| D | $4V_1 = V_2$ |
| E | $V_1 = 4V_2$ |

| $\rho_1$ | Flow | $\rho_2 = \rho_1/2$ |
| $V_1$ | $V_2 = ?$ |

$\rho_1$ = fluid density at location 1
$\rho_2$ = fluid density at location 2
$V_1$ = average velocity of fluid at location 1
$V_2$ = average fluid velocity at location 2

FIGURE 1
QUESTION 1 FROM THE FMCI.

Students understanding. There are also a number of questions that will need to be modified, completely rewritten, or removed. At this point we will keep unchanged questions 1,2,4,5,6 and 7. We will modify questions 9,10,11,14,15,17,19,20,22,23,26 and 27. We will delete questions 3,8,12,16, and 25. We will be replacing these questions with questions on hydrostatic pressure, another problem on pitot tubes, and another problem on shear stress.

ACKNOWLEDGMENT
This work was supported by the Engineering Education Program of the National Science Foundation under Award Number EEC-9802942

REFERENCES


SUMMARY
Item analysis on the FMCI has shown that there are a number of questions that appear to be doing a reliable job of indicating