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# Assessing Students' Performance on Material Technology Course through Direct and Indirect Methods

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## ABSTRACT

Student performance of technical expertise at the end of the learning process is very important. The achievement of Course Outcomes (COs) must be tracked every semester and counteractive action must be carried out if the achievement does not meet the performance criteria that has been set. This paper will assess student performance for each CO for the course, Material Technology using direct and indirect assessment and triangulation as the result of continuous quality improvement (CQI). Direct assessment was measured using assignment, final examination, project presentation and laboratory report, while indirect assessment was measured using a pre-test and post-test survey. The item constructs of pre-test and post-test questionnaires were validated using the Rasch measurement model. The direct and indirect assessments were compared and the results revealed that differences exist between students' perception of their learning and their actual learning. The findings indicate that there is an inconsistency between students' perception of their learning (indirect assessment) and their attainment of knowledge and practical skills as rated by their lecturers (direct assessment). Thus, indirect measurement alone is not a valid measure of student learning achievement.

*Keywords*: Direct assessment, indirect assessment, Course Outcomes (CO), material technology course

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## INTRODUCTION

Outcome-Based Education (OBE) has become a critical aspect of accreditation requirement by the Engineering Accreditation Council (EAC), which

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represents the Board of Engineers Malaysia (BEM). Outcome-Based Education (OBE) is an approach that focusses on behaviour change in the learning of students rather than on the learning process. It is designed to be an open system that complies with a set of predefined outcomes. It is also a student-centred learning process that focusses on measuring student achievement of the outcomes outlined in each course. At the Faculty of Engineering and Built Environment (FKAB), Universiti Kebangsaan Malaysia (UKM), every lecturer is required to discuss and establish Course Outcomes (COs) for every course teaching plan. Firstly, the COs are clearly defined, then the curriculum is designed to realise the outcomes. Curriculum and teaching depend on how best to facilitate the desired outcomes. This leads to a planning process that is different from traditional educational planning. Each course must address a specific and measureable set of COs. The COs define the goals of learning explicitly. Lecturers assist in the preparation of lectures while students concentrate on improving their performance, knowing the goals of the course that they are pursuing. Indirectly, the COs also spawn criteria that need to be measured (Lee et al., 2009). The introduction of the OBE system has led to a significant amount of work in the development and assessment of these outcomes in students.

## Assessment of Learning Outcomes

Assessment is the systematic and ongoing process of collecting, interpreting and acting on information related to the goals and outcomes developed to support an institution's mission and purpose. Generally, the assessment process involves (1) studying activities (courses, co-curricular events like a lecture series, fieldwork etc.) that are designed to meet specific goals (in this case, COs); (2) determining if goals are being met; and (3) adapting activities/goals as appropriate if goals are not being met (Suskie, 2004). Students benefit from assessment because assessment feedback helps them understand their strengths and weaknesses. On the other hand, instructors and lecturers also acquire some benefit because assessment activities bring lecturers together to discuss important issues such as what is to be taught and why as well the standard and expectations for student learning.

Different methods of assessments are used by different institutions; however, most of them are based on direct and indirect assessment. Triangulation of results provides a better judgement of the achievement of COs. Direct assessment methods require learners to display or demonstrate their knowledge, behaviours and/or thought processes. In FKAB, the assessment tools that are always used are the tutorial, examination, laboratory exercise and presentation. Indirect measures are in contra-distinction to direct measures. Indirect assessment methods require learners to reflect upon their knowledge, attitude, behaviour and/or thought processes (Colosi & Dunifon, 2006). For the course, Material Technology, which is offered to second-year students of the Civil and Structural Engineering programme, indirect assessments contain a set of pre- and post-test questionnaires. This most common evaluation design is normally used to collect information on student perception bebefore and after course/programmes, that is at two time intervals, to accurately detect any changes in the participant. The participants are asked a series of questions both at the beginning (pre-test) and then again at the course/programme's completion (post-test) ( DeMaio et al., 1998; Colosi & Dunifon, 2006).

Here, the purpose of using a pre- and post-test is to identify student perception before and after undergoing the process of learning on the course, Material Technology. The pre-test itself can assess the quality of the questionnaire and the research study. It can provide useful information regarding the quality of data that will be collected in real research (DeMaio et al., 1998). Conventional pre-tests also are based on the assumption that questionnaire problems will be signalled by the answer that the questions elicit (Presser et al., 2004). Good quality research data are dependent on good items in the questionnaire that are not misleading. However, the quality of pre-test questions is often overlooked and these items are not re-tested. Consequently, the findings of the study do not reflect the expected results (DeMaio et al., 1998; Azrilah et al., 2012).

The importance of item constructs should be emphasised. Construct validity defines how well a test measures up to its claim and it can be validated using the Rasch measurement model (Roszilah et al., 2011; Azrilah et al., 2013; Siti Aminah et al., 2015). The Rasch measurement model has been widely used today as an approach to improving the methods of teaching delivery and student assessment. This model was introduced by Georg Rasch, a mathematician from Denmark. Rasch's theory puts a person with high ability or excellent results at the top of the ranking in a positive logit scale and the person with weak ability at the bottom position in a negative logit scale. The mediocre person is located between the excellent and weak persons. This model is able to produce a reliable repeatable measurement instrument and can be used to construct an instrument with accuracy (Azrilah et al., 2013).

This paper attempts to assess CO assessments in Material Technology, the course, using direct and indirect assessment and triangulation from the result of continuous quality improvement (CQI). The Rasch measurement model analysis was used in this study to validate the instrument used in the indirect process.

## Context of Study

Materials Technology (coded KKKH2164) is a first-semester, second-year course taught at the Department of Civil and Structural Engineering at Universiti Kebangsaan Malaysia (UKM). The course deals with the introduction of construction materials, their manufacturing processes, their characteristics and properties. This course consists of lectures, project work and laboratory work on concrete mixing and testing. The mix design method of concrete (the most widely used construction material) is emphasised (Roszilah et al., 2012).

Course Outcomes are statements of learning achievement that are expressed in terms of what the student is expected to know, understand and be able to do upon completion of a course. They may also include attitudes, behaviour, values and ethics. Clear articulation of COs serves as the foundation to evaluating the effectiveness of the teaching and learning process. COs must be specific and measureable. The main components to create a measurable CO are: (1) student learning behaviour, (2) appropriate assessment methods, and (3) specific student performance criteria/ criteria for success. Specifying COs can provide specific, clear information for students on what is expected from them; thus, students may find it helpful if COs are discussed at the start and end of a course. COs are different from aims, in that they are concerned with the achievement of the learner, rather than the overall intentions of the tutor. Teaching and learning methods and assessment processes are aligned directly with the learning outcomes. COs for Material Technology are shown in Table 1.

Table 1
*List of Course Outcomes for the Course, Material Technology*

| No. | CO Statements |
|---|---|
| CO1 | Able to understand/explain/discuss the physical and engineering properties of Civil Engineering Materials |
| CO2 | Able to understand/explain/discuss physical and engineering properties of concrete components (coarse and fine aggregates, cement, admixtures) and fresh and hardened concrete |
| CO3 | Able to design concrete mix proportion using DoE or ACI method |
| CO4 | Able to understand/explain/discuss testing of fresh and hardened concrete |
| CO5 | Able to communicate verbally the physical and engineering properties of Civil Engineering materials; physical and engineering properties of concrete components (coarse and fine aggregates, cement, admixtures); physical and engineering properties of fresh and hardened concrete and testing of fresh and hardened concrete to members in class |
| CO6 | Able to apply testing methods to determine the properties of fresh and hardened concrete under minimum supervision |
| CO7 | Able to analyse the different types of concrete depending on intended application and requirement for strength and environment. |

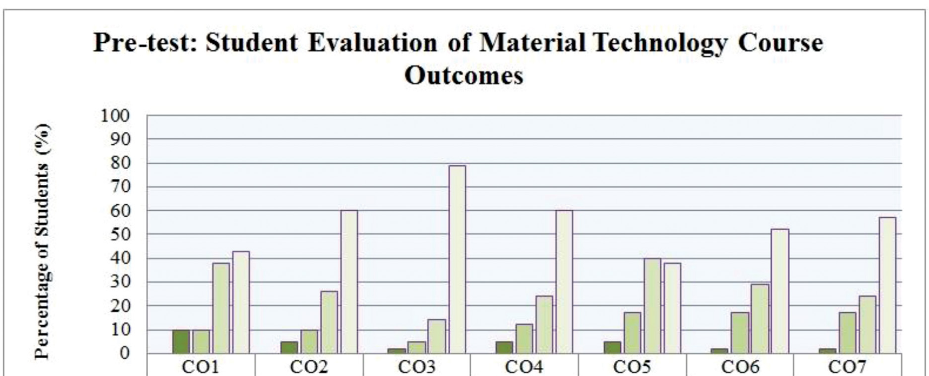
## METHODOLOGY

### Indirect Assessment

An indirect assessment is useful in that it can be used to measure certain implicit qualities of student learning, such as values, perception and attitudes from a variety of perspectives. For Material Technology, indirect measurements are done through questionnaires at the beginning (as pre-test) and final (as post-test) semester.

Pre- and post-tests generally are used in behavioural research to compare groups and/or measure change resulting from experimental treatments. In this case, pre- and post-tests are a measurement of the learning received during the class as a result of comparing what the student knew before in a pre-test and after the class experience in a post-test. It is used to quantify the knowledge attained in the class and indicate how the students are learning in the course. The reason for using a pre-test is to measure a starting point or the amount of pre-existing knowledge of the course outcomes and the reason for using a post-test is to measure learning as a result of the course experience. The set of questionnaires is the same for the pre- and post-test. This design is believed to measure changes in participant knowledge, attitudes or behaviour regarding the course content. In general, measurement is done at two time intervals to accurately detect any changes in the participants.

The test questions required the students to rank their knowledge and ability to understand/discuss and explain what the COs addressed. They were asked to rate their quality of learning experience using the following 5-point Likert scale: 1. Excellent, 2. Good, 3. Fair, 4. Poor, 5. Very poor. The results of the pre-test and post-test are presented in the form of the percentage of students are as shown in Figure 1 and 2.




| | CO1 | CO2 | CO3 | CO4 | CO5 | CO6 | CO7 |
|---|---|---|---|---|---|---|---|
| Excellent | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Good | 10 | 5 | 2 | 5 | 5 | 2 | 2 |
| Fair | 10 | 10 | 5 | 12 | 17 | 17 | 17 |
| Poor | 38 | 26 | 14 | 24 | 40 | 29 | 24 |
| Very poor | 43 | 60 | 79 | 60 | 38 | 52 | 57 |

*Figure 1.* Results of pre-test: Student evaluation of Material Technology COs.

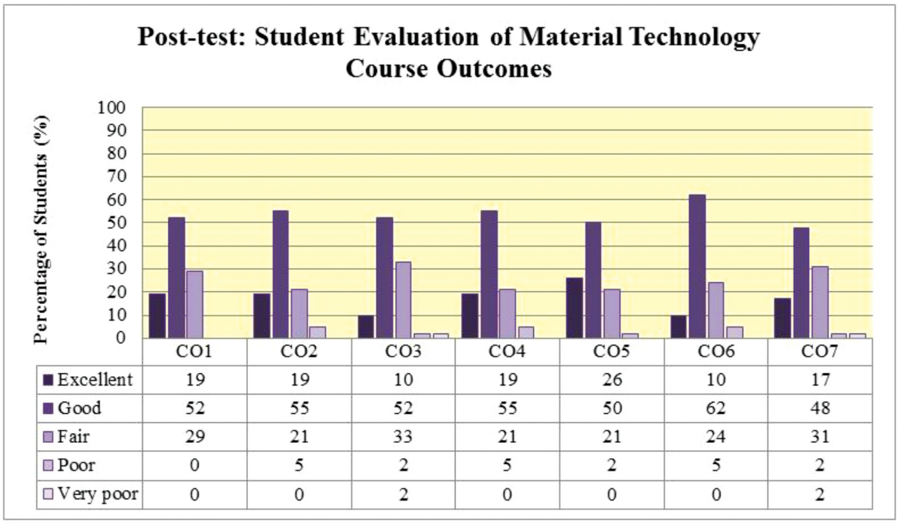



*Figure 2.* Results of post-test: Student evaluation of Material Technology COs.

To validate the item construct for the pre-test and post-test, the responses of 42 students who had filled answered the pre-test questions for the Material Technology course were tabulated in Excel*prn and run in WinStep®, a Rasch software to obtain logit values. The analysis output obtained from WinStep® was analysed to identify reliability and validity.

## Direct Assessment

Lecturers are most familiar with direct assessment (measures). Direct assessment is the direct examination or observation of student knowledge or skills against measurable Course Outcomes. Lecturers conduct direct assessment of student learning throughout a course using different methods such as examination, assignment, project and laboratory work and reports. These techniques provide a real sampling of what students know and/or can do and provide strong evidence of student learning. Table 2 below shows how assessments for each CO are carried out through the semester.

Table 2
*Course Outcomes Assessment Methods and Tools for Material Technology*

| CO | Assessment methods | Assessment Tools |
|---|---|---|
| 1 | Final exam | Marking scheme |
| 2 | Final exam, Laboratory report | Marking scheme, rubric |
| 3 | Final exam, Assignment, Laboratory report | Marking scheme, rubric |
| 4 | Final exam, Assignment | Marking scheme |
| 5 | Project presentation | Rubric |
| 6 | Laboratory work | Rubric |
| 7 | Laboratory report | Rubric |

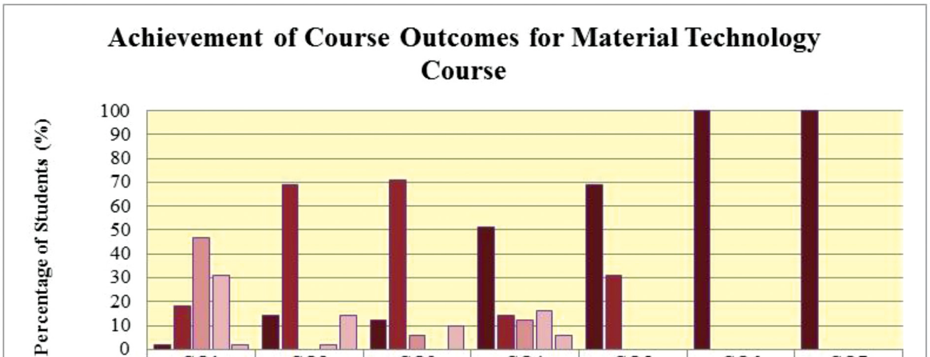
In the course, Material Technology, the measurement of CO achievement is the total marks obtained by the students from all the assessment methods that are specific to the respective COs as shown in Table 2. The calculation is done without applying any weightage. Steps for calculating CO achievement scores use the following equation:

$$\frac{\textit{total marks obtained by students}}{\textit{total marks allocated for all assessments}} \; \textit{x } 100\% = \textit{CO achievement} \qquad (1)$$

The mark obtained from each student is ranked into five levels of achievement. Table 3 shows the ranking for CO achievement by the student. The results of CO achievement through direct measurement are shown in Figure 3.

Table 3
*Ranking of CO Achievement in Material Technology*

| COs Scores (%) | Description |
|---|---|
| 81-100 | Excellent |
| 61-80 | Good |
| 41-60 | Fair |
| 21-40 | Poor |
| 0-20 | Very poor |




| | CO1 | CO2 | CO3 | CO4 | CO5 | CO6 | CO7 |
|---|---|---|---|---|---|---|---|
| Excellent | 2 | 14 | 12 | 51 | 69 | 100 | 100 |
| Good | 18 | 69 | 71 | 14 | 31 | 0 | 0 |
| Fair | 47 | 0 | 6 | 12 | 0 | 0 | 0 |
| Poor | 31 | 2 | 0 | 16 | 0 | 0 | 0 |
| Very poor | 2 | 14 | 10 | 6 | 0 | 0 | 0 |

*Figure 3.* Achievement of Material Technology COs.

## DISCUSSION

### Instrument validation

From the output of WinStep®, summary statistics and the Item Measure Order were established. In WinStep® output, person represents the students while item represents the test questions. Table 4 shows the summary statistics of the pre-test and post-test. The summary statistics contained information on mean, standard deviation, minimum and maximum value, reliability and separation. For the pre-test, the summary statistics revealed that the consistency of the raw score was good, with a Cronbach Alpha value of 0.93. This validated the model as acceptable. The student reliability value was 0.80, indicating that there was a good spread of student ability within the sample that was used (Azrilah et al., 2013). The person ability spread between was maximum +26.0 logit and minimum +7.0 logit, while the mean person value was at +11.6 logit. The students could be grouped into approximately two groups (e.g. disagree, agree) based on the student separation value, G = 2.00, while the item could be grouped into two groups.

The purpose of the item measure table, as shown in Table 5 was to check the validity of the items which had three controls to be compared: point measure correlation, outfit MNSQ and outfit ZSTD. The range of acceptable criteria for each control was as follows: Point Measure = $0.4 < x < 0.8$; Outfit MNSQ = $0.5 < y < 1.5$; Outfit z-standard (ZSTD) = $-2 < z < 2$. Other than determining construct validity, analysis of the point measure correlation defined if the correlation was small. A small correlation meant that many students could not answer the question. If all three controls were not met, the question would be considered a misfit question. The results revealed that none of the questions was out of the range of the acceptable criteria. Therefore, all the questions were fit and valid; hence they could be used in the post-test.

Table 4
*Summary Statistic for Indirect and Direct Assessment of Material Technology*

| Summary Statistics | | Mean | SD | Max | Min | Cronbach Alpha | Reliability | Separation, G |
|---|---|---|---|---|---|---|---|---|
| Pre-test | Student | 11.6 | 4.9 | 26.0 | 7.0 | 0.93 | 0.80 | 2.00 |
| | Item | 69.6 | 7.4 | 49.0 | 55.0 | | 0.85 | 2.38 |
| Post-test | Student | 26.8 | 4.1 | 35.0 | 17.0 | 0.88 | 0.87 | 2.51 |
| | Item | 160.9 | 4.7 | 168.0 | 153.0 | | 0.53 | 1.07 |

Table 5
*Item Measure Order for Pre-test of Material Technology*

| ENTRY NUMBER | TOTAL SCORE | COUNT | MEASURE | MODEL S.E. | INFIT | | OUTFIT | | PT-MEASURE | | EXACT | MATCH | Item |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MNSQ | ZSTD | MNSQ | ZSTD | CORR. | EXP. | OBS% | EXP% | |
| 3 | 55 | 42 | 4.74 | 0.39 | 0.71 | -0.9 | 0.45 | -0.5 | 0.74 | 0.67 | 83.3 | 82.3 | CO3_B |
| 2 | 67 | 42 | 3.34 | 0.31 | 0.75 | -1 | 0.52 | -1.1 | 0.82 | 0.75 | 76.2 | 70.1 | CO2_B |
| 4 | 68 | 42 | 3.25 | 0.3 | 0.93 | -0.2 | 0.86 | -0.2 | 0.78 | 0.75 | 76.2 | 69.8 | CO4_B |
| 7 | 69 | 42 | 3.16 | 0.3 | 1 | 0.1 | 0.8 | -0.4 | 0.77 | 0.75 | 76.2 | 69.5 | CO7_B |
| 6 | 71 | 42 | 2.99 | 0.29 | 1.24 | 1 | 1.87 | 1.9 | 0.69 | 0.76 | 73.8 | 67.8 | CO6_B |
| 1 | 78 | 42 | 2.44 | 0.27 | 1.05 | 0.3 | 1.09 | 0.4 | 0.77 | 0.77 | 69 | 64.3 | CO1_B |
| 5 | 79 | 42 | 2.36 | 0.27 | 0.77 | -1.1 | 0.89 | -0.3 | 0.79 | 0.77 | 69 | 63.6 | CO5_B |
| MEAN | 115.2 | 42 | 0 | 0.3 | 0.97 | -0.1 | 0.99 | 0.1 | | | 71.3 | 68.6 | |
| S.D. | 46.1 | 0 | 3.24 | 0.03 | 0.16 | 0.7 | 0.32 | 0.7 | | | 6.1 | 4.4 | |

Back to Table 4, the summary statistics for the post-test showed that there were no big differences with the post-test results. The value of the Cronbach Alpha was 0.88, showing that the consistency of the raw score was good. The student reliability value was 0.87, also indicating that there was a good spread of student ability within the sample that was used. The persons' ability was spread between maximum +35.0 logit and minimum +17.0 logit while the mean person value was at +26.8 logit. Based on the student separation value, G = 2.59, there were approximately three groups of students while the item could be grouped into only one group separation (G=1.07).

## Results of Direct and Indirect Assessments

The results of the two tests i.e. the pre- and post-test for indirect measurement both showed positive trends from the start to the end of the course. Referring to Figure 1, more than 80% of the students ranked their knowledge and ability to understand/ discuss and explain all the COs addressed in Material Technology as poor and very poor except for CO5. This was because CO5 addressed communication skills. Students had taken compulsory university courses in their first year that taught them how to improve their interpersonal skills. For the remaining six COs, however, they had an almost zero starting point of pre-existing knowledge about the course. However, by the end of the course, students perceived that they had understood and were knowledgeable in the seven COs. More than 60% of the students ranked their perception of the seven COs as excellent, good and fair.

On the other hand, direct measurement showed the real achievement of students. There was a difference between what students felt or expected and their actual knowledge and understanding as proven through marks scored on the examination and for coursework. Figure 3 shows that 100% of the students excelled in CO6 (Able to apply testing methods to determine the properties of fresh and hardened concrete under minimum supervision) and CO7 (Able to analyse the different types of concrete depending on intended application and requirement to strength and environment). Figure 3 also shows that 33% and 22% of the students had difficulty understanding the content of CO1 (Able to understand/explain/discuss the physical and engineering properties of Civil Engineering materials) and CO4 (Able to understand/explain/discuss testing of fresh and hardened concrete), respectively.

Analysis of students' final grades for the direct method and the results of student self-assessment questionnaires in the indirect method are compared and it was found that there was a definite difference. Students felt that they were knowledgeable in CO1 and CO4 but in reality, they could not really answer the questions on those respective COs in the examination and coursework. This shows that the students had overestimated their understanding of certain COs.

To make a clearer comparison, the number of students who had achieved the target set, which was fair and above for both assessments, were added up and compared. Table 6 and Figure 4 show the percentage of students who scored 'fair', 'good' and 'excellent' for both assessments. For the indirect assessment, the post-test was chosen because it was a reflection of student expectation of their knowledge at the end of the semester. The analysis showed that there were clearly a difference between the percentage of student achievement for CO1, CO2 and CO4 between the direct and indirect assessment method, which was 33%, 11% and 16%, respectively. Based on the results of direct assessment, the students seemed to find it difficult to understand or explain or discuss the basic Material Technology course. The gap difference was more than 10%; this was quite a big gap, showing that indirect assessment alone is not valid for determining student achievement. Lecturers need to know student expectations to develop a good continual quality improvement process. Meanwhile, for the rest of the Cos, which are CO3, CO5, CO6 and CO7, the gap difference was below 10%.

Table 6
*Comparison of Student Achievement of COs from Indirect and Direct Assessment for Material Technology*

| Course Outcomes (COs) | Indirect Assessment (Post-test) | Direct Assessment | Difference |
|---|---|---|---|
| CO1 | 100 | 67 | 33% |
| CO2 | 95 | 84 | 11% |
| CO3 | 95 | 90 | 5% |
| CO4 | 95 | 78 | 17% |
| CO5 | 98 | 100 | 2% |
| CO6 | 95 | 100 | 5% |
| CO7 | 95 | 100 | 5% |

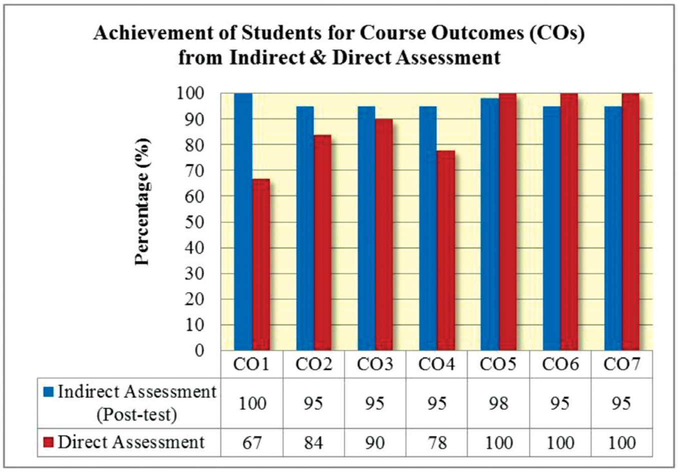



*Figure 4.* Achievement of students for course outcomes (COs) from indirect and direct assessment in Material Technology.

## CONCLUSION

Direct and indirect assessment are both needed for attainment of Course Outcomes as seen from two different perspectives i.e. from lecturers and from students. The results of the analysis using both direct and indirect methods showed that three COs reflected extreme confidence on the part of students and another four COs reflected lack of confidence in students' perception. In addition, this study also stressed on the validity of the pre-test. The finding shows that the items that were used in the pre-test were good and acceptable and could be used in the post-test. It is important to consider that the post-test findings will be used to make a comparison between student perception and their real achievement. The Rasch Measurement Model was found to be an effective method to determine the test questions' construct validity and to identify misfit items.

In the continous quality improvement process, all stakeholders' opinions need to be considered. In this case, students are one of the stakeholders, and their expectations through indirect measurement is an important point to be noted. Combinations of the two assessments create a platform for holistic assessments. Holistic assessment is focussed on the whole process; the entire involved person is discussed as education is a two-way communication process that involves both students and lecturers.

This study provided a unique perspective of the assessment of learning comparing results from direct and indirect measures in Material Technology. The findings suggest that student perception of learning is not essentially reflective of knowledge content and practical laboratory skills mastery. Perception of learning seems to be a distinct construct from actual learning, and it may reflect student satisfaction with their experiences in the course, rather than their achievement of content and skills. Thus, student satisfaction with their educational experience deserves the attention of lecturers and administrators who are interested in improving programme quality.

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