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Measuring Student Performance and Providing Feedback using Competency Framework

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***Abstract*—A number of Computer Science and Information Systems programs have effectively defined learning outcomes, course level competencies, and conducted assessments at the program level to determine areas for continuous improvement. However, many of these programs do not fully leverage the course competencies during the actual delivery and assessment of the course. This paper presents how course competencies can be used to effectively deliver and assess the course content, and give valuable timely feedback to the students. Using a large first year core course of the BSc (Information Systems Management) program (called Object Oriented Application Development course-OOAD) as an example, this paper shows how the course competencies support the five phases of the Course Life Cycle and Competency Framework.**

Keywords— Competency Framework, Course Life-Cycle, Student Assessment, Course Delivery and Performance Feedback.

I. INTRODUCTION

The specification and continuous assessment of student outcomes and competencies have become a central focus in undergraduate and postgraduate engineering and business education. In order to be accredited, ABET (Accreditation Board for Engineering and Technology), requires the program to have defined student outcomes and an effective process for the periodic review and revision of these student outcomes. Furthermore, it requires the program to regularly use appropriate, documented processes for assessing and evaluating the extent to which the student outcomes are being attained [1]. The Advance Collegiate Schools of Business (AACSB) emphasize "direct assessments of student learning through the formulation of specific learning goals and the conduct of direct assessments of learning goal attainment". Therefore, a number of engineering and IS education programs have effectively defined learning outcomes, course level competencies, and conducted assessments at the program level to determine areas for continuous improvement. However, many of these programs do not fully leverage the course competencies during the actual delivery and assessment of the course.

The main contribution of this paper is to demonstrate using the OOAD course as a case study, how competencies can be used across the entire lifecycle of a course. In the next section a brief background to the area of competency-based learning programs is presented. Section 3 uses the OOAD course to walkthrough the various phases of a course lifecycle and show how competency can be effectively utilized in these phases. Section 4, presents an evaluation of the framework using the results of the student survey. In Section 5, some of the challenges faced during the implementation of the competency-based approach are discussed and opportunities for future enhancements of the approach are presented.

II. RELATED WORK

For the purpose of this paper we adopt the definition of competency as defined by [7], "Competencies are defined as the knowledge, skills and abilities in the context of a specific domain (e.g. object oriented application development, cloud computing, etc.) that enable a student to take an effective action or make sound decisions". The knowledge here includes factual, conceptual, procedural, and meta-cognitive, as defined by [2].

Competency-based learning programs have been part of the education systems in different countries for several decades; however, most of such programs have been implemented in the professional or vocational training sector [4]. More recently, higher education institutions are attempting to reshape their programs with a more professional orientation. For example, [5] proposes that education should focus on competency level training and assessment and make students "industry ready". In Computer Science and Information Systems programs the dual challenge of continuous evolvement of the discipline and the issue of appropriate employment of graduating students have driven the need for competencies-based teaching and learning [8]. [8] presents an approach to structure the curriculum by defining the competencies as the instructional goals and subsequently defining the conceptual requirements to achieve these goals. Some studies have focused on using competency mapping approaches to understand what students actually learn in a programming course without actually requiring them to take extra assessments [6]. However, very little work has been done in exploring how competencies can be used across the entire lifecycle of a course [3]. In this paper we focus on this gap and show using a programming course as an example, how competency-based approach can be applied across the various phases of the course lifecycle.

III. OOAD CASE STUDY

Fig. 1 presents the Course Life Cycle and Competency (CLCC) framework. This framework consists of five phases, namely content design, assessment design, content delivery & assessment, assessment feedback, and content review.

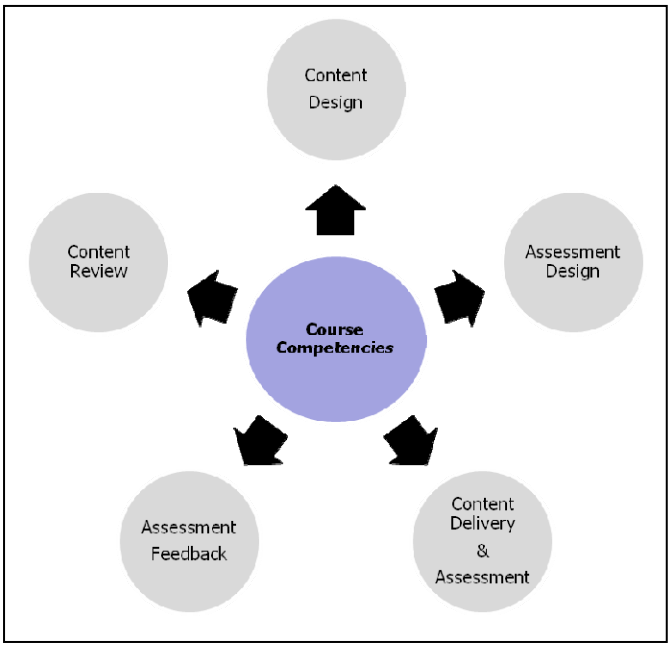

Fig. 1. Course lifecycle and competency framework.

In actual practice, many of these phases are highly iterative, involving a lot of small iterations. In the following subsection, using the Object Oriented Application Development course as an example, we describe how the course-level competencies are related to each of these five phases.

OOAD is a foundation course of the BSc (IS Management) program delivered in the second semester of the first academic year. This course focuses on the analysis and design phases of the software development lifecycle. Each year, around 280 students take the OOAD course and are divided into seven sections of about 40 students each. Each section is managed by one faculty, one instructor and one teaching assistant. The entire teaching team is present in all classes allowing efficient support during class exercises and lab sessions as well as consultations outside of class time.

A. Content Design

About 40 core competencies were defined for the OOAD course. During the Content Design phase, based on these competencies, the course team decides on the topics and the hands-on labs that will provide opportunity to acquire the competencies, and course assessments that will demonstrate the acquisition of the competencies. The competency matrix [3], which comprises the mapping of learning outcomes to the core competencies specific to the OOAD course is used to identify the topics and the sequencing of these topics as follows: (1) OO Concepts and UML Basics; (2) Use Case Realization; (3) Design Principles; (4) File and Exceptions handling; (5) Class design; (6) Arrays and Collections; and, (7) Inheritance. For each of these the detailed content is teased out together with appropriate delivery methods such as lecture, discussion, and labs. The key tools to be used in the course are selected which include Astah, Visual Paradigm, Java SDK, DOS prompt and Notepad ++. For ensuring the application of the seven topics identified, seven labs are designed, each lab addressing one topic. This preparatory work is a necessary step to enable students to acquire the required core competencies. Additionally, the number and type of assessments is also identified which include two quizzes, two lab tests, one project and a final exam. The scope and schedule of each assessment is then decided in accordance to the competencies that are to be assessed.

Table 1 shows the mapping of competencies to topics, the competencies covered each week and the corresponding assessments that are used to assess the acquisition of these competencies. However, since a particular assessment cannot test all competencies, the three additional columns are introduced namely scope, focus and tested. The "scope" identifies the topics and competencies that may be included in the particular assessment. This is what the students will be informed. The "Focus" further identifies the topics and competencies which the teaching team will be focusing on while designing the assessment. The students are not informed of this. Only the "scope" column is shared with the students, the "focus" column is shared with the teaching team. So in other words, the "focus" is a subset of the "scope". For example, in Table 1, the competencies in "scope" are C1 to C4, and "focus" is only on C1, C3 and C4.

TABLE 1. EXCERPT OF THE OOAD MAPPING MATRIX OF COMPETENCIES TO TOPICS, WEEKS AND ASSESSMENTS

#	Topic	Taught in week #	Competency Definition	Quiz 2 week 7		
				scope	focus	tested
C1	OO Concepts and UML basics	1	Understand and apply the basic principles of Object Orientation such as Abstraction, Encapsulation, Modularity (object decomposition) and Hierarchy.	√	√	√
C2	OO Concepts and UML basics	1	Explain the importance of modelling in the context of software development.	√		
C3	OO Concepts and UML basics	1	Explain what a class diagram is and relate it to code and vice versa.	√	√	
C4	OO Concepts and UML basics	2	Know how to represent a class diagram using the UML notation.	√	√	√

However, having defined the "focus", the faculty is not constrained to follow the topics and competencies included in the "focus" column. So once the actual questions are completed, the "tested" column is used to record the actual

topics and competencies tested in the particular assessment. This is done during the "Assessment Design" phase.

B. Assessment Design

During this phase, the details of each assessment are teased out. This is done with the help of the competency to assessment mapping matrix shown in Table 1. Having decided the number of questions, the content of each question is designed taking into consideration the competencies that are identified as being in scope and focus. Grading scheme and rubrics are also established at this stage and the actual set of competencies tested by each question is recorded in the mapping matrix as shown in Table 2.

In the example shown in Table 2, in Quiz 2, question Q1 and Q2 test the competency C1, and Q3 tests competencies C3 and C4. Also note that Competency C2 is not tested in Quiz 2, this is in alignment with Table 1, which shows that C2 is in scope but not tested in Quiz 2. However, note that C2 will be tested in another assessment, for example the final exam.

During this phase, the teaching team must also establish a threshold or minimum number of marks. Any student scoring above this threshold is deemed to have acquired the corresponding competencies addressed by that question (see Table 3).

TABLE 2. EXCERPT OF THE OOAD MAPPING MATRIX OF COMPETENCIES TO ASSESSMENT QUESTIONS

#	Topic	Taught in week #	Competency Definition	Quiz 2		
				Questions		
				Q1	Q2	Q3
C1	OO Concepts and UML basics	1	Understand and apply the basic principles of Object Orientation such as Abstraction, Encapsulation, Modularity (object decomposition) and Hierarchy.	√	√	
C2	OO Concepts and UML basics	1	Explain the importance of modelling in the context of software development.			
C3	OO Concepts and UML basics	1	Explain what a class diagram is and relate it to code and vice versa.			√
C4	OO Concepts and UML basics	2	Know how to represent a class diagram using the UML notation.			√

TABLE 3. ASSESSMENT QUESTIONS, MAXIMUM MARKS AND QUESTION THRESHOLD

Questions within Quiz 2	Q1	Q2	Q3
Maximum Marks	4	6	5
Question Threshold Marks	3	4.5	4

There is no limitation to the number of competencies that can be tested by a question but a small number of competencies are advised to facilitate the analysis of results and the feedback phase. The recommended number is between 1 and 3. At the end of the assessment design, across all the assessments it is necessary to ensure that all competencies are tested at least once.

C. Content Delivery and Assessment

Each week, the OOAD course is delivered through a 3 hour face-to-face class session. The course extends over a 15 week period. The labs are also conducted within the 3 hour session. Each week, the concepts and principles related to the topic are presented and discussed, followed by lab work that highlights the application of the concepts and principles learnt. Before each session, students are presented with the competencies that are to be acquired during the session. This helps the students to focus on "what competencies are to be acquired" rather than "what concepts or principles will be covered".

One week prior to every assessment, the competencies that are within the scope of that particular assessment are highlighted. This is meant to help students, when preparing or revising for the assessment, to focus their attention on what competencies they will be tested on rather than the list of topics they need to cover for the assessment.

D. Assessment Feedback

During this phase, the faculty analyse the assessment scores and present the feedback to the students. This is done immediately after the assessment is marked. The standard practice of presenting the scores, averages, etc., is adopted. In addition, and more importantly, a detailed walkthrough of the cohort competency acquisition map is conducted. The cohort competency acquisition map contains the different competencies assessed in the particular assessment and for each competency, whether it was acquired or not acquired. The results' analysis informs on the related competency acquisition by students. We look at two sample cases that can emerge from this analysis:

Case 1: Question result shows a high percentage of students having obtained a full score. In this case, the competency (or set of competencies) that the question is supposed to test, is considered as acquired.

In the OOAD example shown in Fig. 2, the question tests the competencies C3 and C4. The specific exercise given was aimed at matching a set of class diagram to the java code that was provided. The result of that question showed that 91% of students across the cohort scored the full score. Therefore one can confidently conclude that the competencies C3 and C4 are acquired.

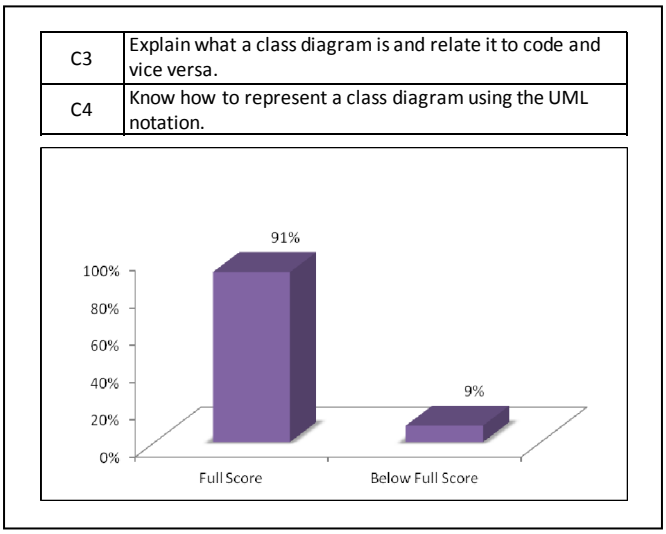

Fig. 2. High percentages of full score to a question.

Case 2: Question result shows a low percentage of students having obtained a full score. In this case, a first look may indicate that the competency has not been acquired. However, to get a more accurate view, a further investigation is necessary to find out the distribution of grades below the full score. A histogram is then used to observe the frequency of answers below the full score. The threshold set during the Assessment Design phase in Table 3, is now used to determine whether the competencies tested for a question with low percentage of full scores is acquired or not acquired.

In the OOAD example shown in Figure 3, one question is out of five marks and the threshold has been fixed to four marks. Any student getting below four marks is considered not having acquired the corresponding competency. Using Figure 3, a quick calculation shows that a majority of students that is 74% (192 students out of 261) of the cohort has obtained four and above, for this question. Therefore the competency is deemed as acquired.

After grading an assessment, the teaching team is then able to establish a list of competencies not acquired as well as common mistakes. The results are presented to students at the immediately succeeding class session after the test was taken. This ensures students are aware of the competencies that are acquired or not globally by the cohort. In addition, a detailed walkthrough of the common mistakes is then conducted through a collaborative session involving student participation. During the session, the students are required to identify their mistakes. Since the assessment occurred the week before, the questions and their answers are still fresh in students' memories so they fully benefit from the review.

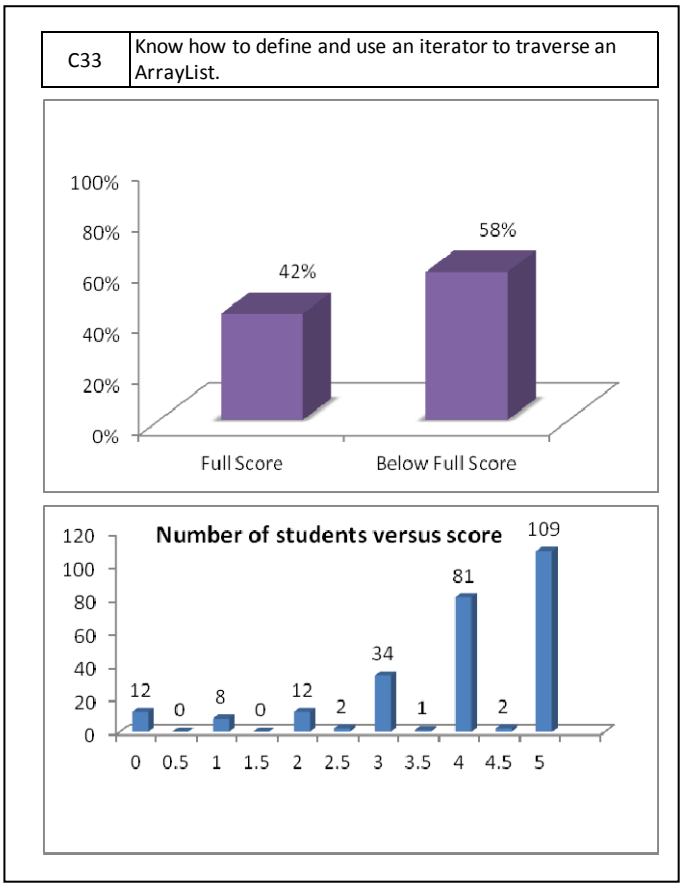

Fig. 3. Low percentages of full score to a question.

In summary, this process allows the teaching team to further delve deep into the details of specific questions not performed well by students and thus gives another chance to enhance the acquisition of competencies by students.

E. Content Review

During this phase, the course team conducts a detailed analysis of the various assessments in the course and the competencies that are acquired or not acquired. For those competencies that are seen as acquired, no additional work is necessary. For competencies that are not acquired, the course team reviews the content covered, the labs, and the assessments associated with those competencies.

In some cases, it happens that an assessment is failed by a large majority of students. The teaching team is then brought to question itself on the reasons, for example, was the topic related to the "competency that was not acquired" addressed clearly in class?, did the teaching team allocate enough time for ensuring students get sufficient hands-on practice to apply the concepts related to the topic?, etc.

Sometimes this analysis leads to a change of content or a change in the sequencing of the topics delivered etc. In any

cases, it gives the teaching team the opportunity to improve the current content and/or pedagogy.

IV. EVALUATION OF THE FRAMEWORK

The evaluation of the effectiveness of the competency-based approach during content delivery and assessment and assessment feedback phases was conducted through a student evaluation survey.

The evaluation survey comprised five quantitative questions and one qualitative question as shown in Table 4. A group of 110 first-year students participated in the evaluation. Some conclusions from the survey data follow:

- The presentation of the competency list helps the students to gain a better understanding of the knowledge and skills they can expect to gain from the course. About 20% of the students found it "very useful" and 68% found it "somewhat useful".
- Before each assessment, students read through the list of competencies that they are likely to be tested on and this helps them prepare for the assessment. Of the group, 79% indicated they carefully read the competency list, of this, 12% found it to be "very helpful" and 74% "somewhat helpful".
- Use of the competencies clearly helps the students to have a better feel of "what they know" and "what they do not know". Of the students, 29% found it to be "very helpful" and 62% "somewhat helpful".
- The use of competencies during the assessment feedback sessions helps to "close the loop" by ensuring the students gained a higher visibility of the exact mistakes they made in the assessment. The survey showed that 40% found it to be "very helpful" and 55% "somewhat helpful.

TABLE 4. STUDENT QUESTIONNAIRE AND EVALUATION RESULTS

	Number of students		31	40	39		
			Section 1	Section 2	Section 3	Average	
1	Rate **how useful** the competency list was in helping you get a **better understanding of the skills** and knowledge that are to be acquired in the course.	Very useful	19%	25%	15%	20%	**87%**
		Somewhat useful	68%	63%	72%	68%	
		Not very useful	13%	13%	13%	13%	
		Not useful at all	0%	0%	0%	0%	
2	When you are given the list of competencies before the assessment, **do you read the list of competencies** provided before each assessment?	Yes	68%	85%	85%	79%	**79%**
		No	32%	15%	15%	21%	
3	If you do read this list of competencies, **does it help you to prepare** for the assessment?	Very useful	15%	13%	9%	12%	**86%**
		Somewhat useful	81%	75%	66%	74%	
		Not very useful	4%	13%	23%	13%	
		Not useful at all	0%	0%	3%	1%	
4	Does the use of competencies **help to raise your awareness** regarding **what you know and what you do not know**?	Very useful	16%	43%	28%	29%	**91%**
		Somewhat useful	74%	53%	59%	62%	
		Not very useful	10%	5%	13%	9%	
		Not useful at all	0%	0%	0%	0%	
5	Does the **presentation of test results**, that explains the competencies that were acquired and those that were not acquired, along with the **review session** help to "close the loop" and **clarify doubts on mistakes** that you made in the test?	Very useful	26%	50%	44%	40%	**95%**
		Somewhat useful	65%	45%	56%	55%	
		Not very useful	10%	5%	0%	5%	
		Not useful at all	0%	0%	0%	0%	

V. CONCLUSIONS AND FUTURE WORK

This paper presented how course competencies can be used to effectively deliver and assess the course content, and give valuable timely feedback to the students. This ensures that "competencies" become an essential part of the learning contract. Using this approach, it enables the course teaching team to regularly use appropriate, documented processes for assessing and evaluating the extent to which the competencies are being attained, thus, "closing the loop" and improving teaching and learning.

However, the implementation of the competency based approach does pose two key challenges namely extra-effort and as a result resistance from faculty.

Currently, the implementation relies on some extra manual work using a spreadsheet tool. This requires a lot of data entry into the spreadsheet. Future work will be aimed at developing a tool that alleviates some of the extra-effort required. Currently, though the spreadsheet approach works well for first year courses, a tool that integrates systematically the learning outcomes and competencies across different courses within a program will be more useful, particularly for satisfying the ABET program assessment requirements.

From a teaching and learning perspective, though grades are captured for each individual student, the current approach focuses on the competency acquisition at the cohort level rather than for individual student. Going forward, it would be valuable to establish, for each student, the list of competencies that have been acquired or not acquired within a specific course and across the different courses in the program.

As of now, the competency-based approach benefits both students and teaching team. It enhances student preparedness, provides enhanced feedback with respect to the competencies acquired, and contributes to "close the loop" in reducing the gap with the competencies not fully acquired.

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