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Targeted Blended Learning through Competency Assessment in an Undergraduate Information Systems Program

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Targeted Blended Learning through Competency Assessment in an Undergraduate Information Systems Program

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***Abstract*— In this paper we report our study on the problem of competency acquisition when students progress from one course to another and more generally, from one term to the next. We observed that some students moved on to a second programming course without acquiring some of the competencies in the first programming course. This leads to problem in the second course, especially when these competencies are pre-requisites for this course. We applied blended learning, which allows a student to learn at least in part through delivery of content and instruction via online media, to overcome this problem. Our approach is unique in the sense that we first assess student competencies and then develop targeted blended learning content to address competencies that have not been acquired in a pre-requisite course. We have applied the method to students doing the first year BSc Information Systems program.**

Keywords—information systems, competency, blended learning, assessment, programming

I. INTRODUCTION

Online content for blended learning in engineering education helps supporting and stimulating student learning in different contexts: during class lessons, refresher courses and reinforcement, and sharing of content with subject matter experts from the industry. In this paper we report on a study undertaken to estimate the efficacy of targeted blended learning content using videos and practice tests as an instrument to support acquisition of programming competencies. Unlike other approaches, the uniqueness of our work is that we first assess student competencies and then develop targeted blended learning content to address competencies that have not been acquired.

Students doing the Information Systems Management Program are required to do the first programming course in Term 1 (August), titled Information Systems Software Foundation (ISSF). This course introduces students to building blocks of programming concepts such as object manipulation, repetition, decisions, etc. In the subsequent semester in Term 2 (January), students' progress to the next course, titled Object Oriented Application Development (OOAD). The course progression is designed such that some of the competencies acquired in the ISSF course are pre-requisites competencies for the OOAD course. These pre-requisite competencies are assessed through the ISSF final exam and detailed analysis of students results show that some of these pre-requisite competencies may not have been acquired by students at the end of the ISSF course. Therefore it is possible for a student to get an overall pass mark in Term 1 for the ISSF course and then move on to the next course OOAD in Term 2, without having the necessary pre-requisite competencies for that course, which is a major issue. Therefore, in January 2013, we put in place an entry-test at the beginning of the OOAD course, based on the pre-requisite competencies that were failed in ISSF, and we informed the students about this test, one week in advance, for allowing proper revision. However, we observed that many students were still unable to demonstrate some of the pre-requisite competencies and failed the "entry test" of the OOAD course, or performed poorly compared to their final exam in ISSF. In order to overcome this problem, in December 2014, we introduced targeted blended learning by developing online videos along with practice tests to enable reinforcement, and students were required to view the videos and attempt the practice tests 2 to 3 weeks before the start of Term 2. A total of 203 students took part in the study. In January 2014 we observed a substantial improvement in the performance in the "entry test" compared to January 2013. We observed that, for similar tested competencies, 85% of the students performed better at the "entry test" of OOAD compared to the final exam of ISSF. A key takeaway from our innovative practice is that a competency driven, targeted blended learning using online videos together with associated practice exercises represents an important tool to refresh and reinforce previous learning in engineering education, and furthermore, to improve the student's progression across the curriculum by ensuring that pre-requisite competencies are acquired before moving on to the next course.

The paper is structured as follows: In Section II we review other related work in the areas of competency based learning and assessment and blended learning. In Section III we present some background information related to our work on the Learning Outcomes Framework (LOF) and the Course Life-Cycle Competency Framework (CLCC) that were developed at School of Information Systems. In Section IV we describe the initial approach adopted along with the results analysis showing the problems observed. Section V presents the

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improved approach using targeted blended learning; we also give a detailed description of the process adopted in our study along with the results. Section VI presents a discussion on the usefulness of the presented approach and areas for future work. Section VII summarizes the conclusions from our work.

II. RELATED WORK

We review two areas of work that are related to the current research, namely competency based learning and assessment and blended learning.

A. Competency Based Learning and Assessment

Many higher education institutions have clearly defined learning outcomes for the program, and competencies for specific courses within the program [9], [14]. Some have also gone further and developed frameworks to successfully leverage the learning outcomes and competencies in a systematic way when designing, delivering or revising a course within the program [4], [5], [6], [17].

Assessment is a crucial component of learning. Hence having defined learning outcomes and competencies, the next step is to define assessments and then to map student performance in these assessments to competencies. For example, the Course Life-Cycle Competency (CLCC) framework developed at the School of Information Systems provides a systematic approach to assess competencies and then uses the results of this assessment to give valuable feedback to both students and instructors teaching the course [17]. Tovar and Soto provide a framework, where they assess basic competencies that high school students must have, before they can embark on a Computer Engineering program [4]. Here the emphasis is on identifying whether the students have the necessary pre-requisite competencies before starting the program. Bekki et al., propose a modified-mastery based learning approach that uses a finite cycle of formative assessments and feedback to demonstrate mastery of the competencies for the course [10]. This is achieved through use of three types of assignments; "evidence assignments", which provide evidence of the students' attempt to learn the topics; "competency assignments", which assess the mastery of a competency; and "enrichment assignments", which present challenges beyond what is covered in the course material and help extend students' understanding of the related topics.

With more and more emphasis on online learning for higher education, e-assessment is also increasingly becoming important. Sitthisak et al., present a system for automatically generating questions from a competency framework, based on question templates, criteria for effective questions, and the instructional content and ability matrix [13]. Ilhai et al., show how a competency based assessment can be extended to online learning environments using assessment grid and feedback [12].

Competencies also provide a means for assessing student progression within the various topics in a course and across different courses in the curriculum [6]. Luca De Coi et al., present the concepts of "input competencies" and "output competences [8]. For a given course, the students apply their prior competency in the context of the given task or problem to demonstrate the "output competency" for that course. Thus the "input competency" may also be defined as pre-requisite competency that the student must demonstrate before starting the course. This concept is very important when looking at competency progression from one course to another course in the curriculum.

B. Blended Learning

In blended learning online learning is systematically integrated with periodic face-to-face interaction with instructor [1]. There have been number of attempts in implementing blended learning in computer science and information systems programs [2]. However, there have been mixed result in terms of effectiveness, where some have reported positive learning impact and others see neutral or not much improvement in learning experience when compared to face-to-face learning.

Hadjerrouit applied blended learning for an introductory Java programming course and observed positive impact on students' learning, which is attributed mainly to well organized and easy, any time access of the content [15]. Perez-Martin and Pascual-Nieta have successfully used blended learning in an operating systems course to encourage students to study after class. The results of this study revealed higher levels of engagement and higher frequency of study [3]. Reza experimented with using guided discovery and blended learning with learning management system in delivering a computer application course to business students with little or no IT background [11]. Analysis of student grades over a four year period strongly supported the blended learning approach. The study conducted in [16] investigated the effect of blended learning on novices' understandings of introductory programming. The study revealed that blended and face-to-face methods had statistically similar effects on academic achievements in terms of the grades. However, face-to-face method was more effective on permanence in terms of retaining the knowledge over a longer period of time compared to the blended method. This highlights that though blended learning has benefits, there could be challenges when teaching certain topics that require deep cognitive processes and new approaches are needed to enhance permanence of learning.

In the subsequent sections, we report our proposed method to enhance blended learning effectiveness by targeting it to specific competencies that students failed to acquire.

III. BACKGROUND

A. Learning Outcomes Framework

Several frameworks have been proposed to incorporate learning outcomes and competencies into engineering education [9] [12]. In Figure 1, we show the key components of the Learning Outcomes Framework (LOF) implemented at the School of Information Systems, Singapore Management University [7].

The LOF consists of three major components: learning outcomes, competencies and assessments. While the learning outcomes have been established at the program level, competencies and assessments are defined at the individual course level.

For each 1st level learning outcome, several 2nd level learning outcomes have been defined (not shown in the figure), and each 2nd level learning outcome has several competencies attached to it. For a complete list, please refer to [5] and [7].

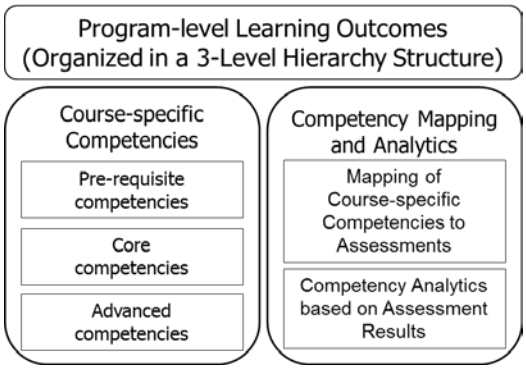


Fig. 1. Key Components of the Learning Outcomes Framework

The second important component of the LOF is competencies. Contrary to the learning outcomes which are defined at the program-level (and are, thus, common for all core as well as elective program courses), the competencies are defined at the individual course level. These competencies are defined by the teaching staff to describe "what the student is capable of doing" on completing the course. Core competencies refer to those competencies that all students are expected to acquire and demonstrate on completing the course.

For a specific course, in addition to the core competencies, two additional competencies can be defined namely, pre-requisite and advanced. Pre-requisite refers to the competencies that a student must acquire and demonstrate before starting a course; these are used as building blocks for the course in question. Advanced refers to those competencies that a subset of students doing the course may acquire and demonstrate on completing the course. Table 1 shows a sample set of core, pre-requisite and advanced competencies for the OOAD course.

When designing a curriculum it is best practice to have some higher level courses build on competencies acquired in the lower level courses. In the School of Information Systems Curriculum, course progression is designed such that the Object Oriented Applications Development (OOAD) course builds on the competencies gained in the previous course namely, Introduction to Software Foundations (ISSF). Therefore, a number of competencies in ISSF course form the pre-requisite for the OOAD course.

The third component of the LOF is assessments. The competencies are mapped to individual assessments in a course and the results of the assessments are analysed. This analysis provides insights into the extent to which the competencies have been acquired by the students. Several methods of assessments are used in the student evaluation process namely labs, quiz, project, exam, and case studies. For measuring the alignment within a course, in our framework, we use the course level competencies and assessments defined in the course.

TABLE I. SAMPLE SET OF COMPETENCIES FOR OOAD COURSE

Pre-requisite Competencies	• Explain the difference between classes and objects and know how to create an object using default or specific constructors. • Use effectively conditional constructs in Java to control the path of execution of statements. • Manipulate efficiently boolean, equality and relational operators used in conditional and repetition Java constructs. • Use and apply ArrayList structures for managing collections of similar classes of objects in Java • Know how to draw a memory state diagram to deduct an output trace. • …
Core Competencies	• Understand and apply the basic principles of object orientation such as abstraction, encapsulation, modularity (object decomposition) and hierarchy. • Using the UML notation, create various design artifacts (such as use case model, domain model, sequence diagrams and class diagram) to fulfil a given set of functional requirements. • Read from a file and write to a file. • Know how to use and apply HashMaps structures versus ArrayLists structures in Java, for efficiently solving a problem. • …
Advanced Competencies	• Understand and apply appropriately CSVReader and CSVWriter provided by the Java library. • …

B. Course Life Cycle and Competency Framework

The Course Life Cycle and Competency framework, Figure 2, is adopted for delivering the introductory programming courses namely, ISSF and OOAD courses. In this approach, course competencies are leveraged during the five phases of a course, namely, content design, assessment design, content delivery and assessment, assessment feedback, and content review. In this paper we briefly describe the assessment feedback phase. The reader may refer to [17] for more details of this framework and the other phases.

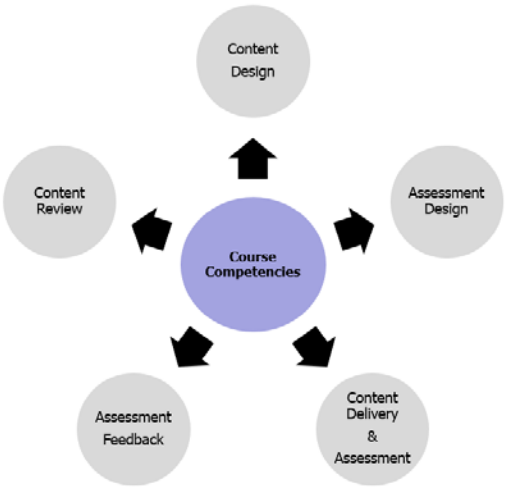


Fig. 2. Course Life Cycle and Competency Framework (CLCC)

During assessment feedback, the instructor analyses the assessment scores and present 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 map contains the different competencies assessed in the particular assessment and for each competency, whether it was acquired or not acquired. The question thresholds set during the Assessment Design Phase are used to determine which competencies are acquired or not acquired.

For the questions, where the score is below the threshold, the related competencies for those questions are considered as not acquired. In this case, a detailed walkthrough of the common mistakes is conducted through a collaborative session with the student's participation.

Though the feedback is given at the cohort level, individual students will know their own mark for specific questions, and hence indirectly can identify the competencies they have fully acquired or not acquired.

In the next two sections, we describe the process and results analysis without and with targeted blended learning respectively. Both the approaches use the LOF and the CLCC framework across the various phases of the course life-cycle.

IV. PART 1: WITHOUT BLENDED LEARNING

A. Process

Figure 3 shows the process for progression from ISSF to OOAD course, during the academic year 2012-2013. The Course Life Cycle and Competency framework is adopted for delivering the ISSF course in Term 1.

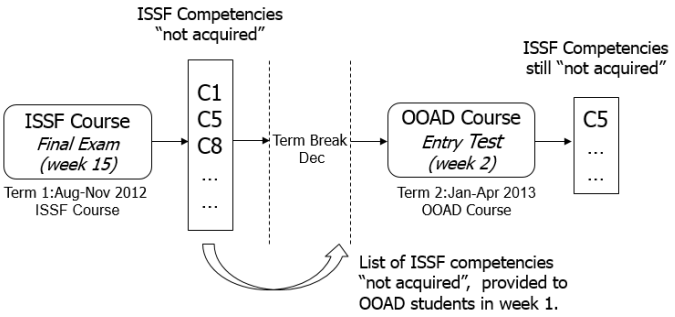


Fig. 3. Process without blended learning

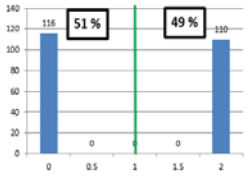
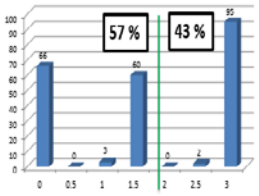
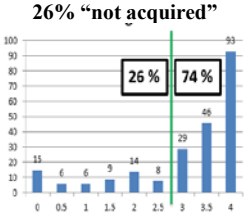
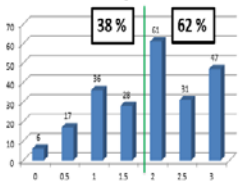
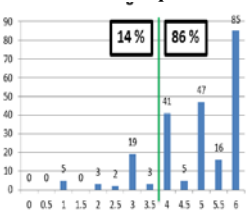
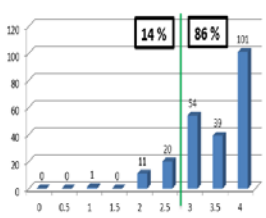
At the end of each assessment, the students' results are analyzed and competencies not acquired by students are identified. Then using this result, an in-class walkthrough of common mistakes is conducted. This is done with active participation of the students, for example, by asking them to identify the mistakes done in the assessment. This approach provides an efficient way to "close the learning loop" by clarifying doubts and therefore reducing the understanding gap.

At the end of ISSF course the final exam tested the students on all the ISSF competencies (which are also pre-requisite competencies for the OOAD course). After the ISSF final exam grading, a consolidated competency acquisition map was produced. This map revealed, for the entire cohort, those competencies that have been "acquired" and "not acquired". The focus was then shifted only to competencies that have not been acquired. However, even if some competencies are "not acquired", it is still possible for a student to get an overall pass mark in the ISSF course and then move on to do the next course namely, OOAD in Term 2. As discussed earlier, a set of the competencies in ISSF course form the pre-requisite competencies for the OOAD course. Therefore, this leads to a problem, where students do not have the necessary set of pre-requisite competencies before embarking on the OOAD course. To alleviate this problem, it was necessary to ensure that students revisit the content related to ISSF course and acquire the pre-requisite competencies required by the OOAD course. So, in the Week 2 of OOAD course, students were tested on some of the ISSF competencies, especially, those that have been deemed as "not acquired". Students were informed of the test in Week 1 of the OOAD course and given a week to prepare for the test. To help them revise, the list of the ISSF competencies "not acquired" was given to them.

B. Competency Acqusitions Results Analysis

Table II shows the results that compare the competency acquisition map across the "ISSF Final Exam" and "OOAD Entry test".

TABLE II. COMPARSION OF COMPETENCY ACQUISITION WITHOUT BLENDED LEARNING

Comp. Tested	*In ISSF Final Exam* — *Competency Acquisition (% of students)*	*In OOAD Entry Test* — *Competency Acquisition (% of students)*
C30 C37 C38	**51% "not acquired"** 	**57% "not acquired"** 
C25 C26 C9 C14	**26% "not acquired"** 	**38% "not acquired"** 
C13 C24 C26 C7	**14% "not acquired"** 	**14% "not acquired"** 

In Academic Year 2012-2013, there were 226 students who completed the ISSF course and progressed to the OOAD course. As seen from the results, there was no improvement in the competency acquisition. In fact, for the first two sets of competencies, there was a decrease of 6% and 12% respectively, and for the third set, no change. These results lead to the following conclusions:

- Neither the one week preparation time that was given to students nor did the list of competencies help them.
- Some students may have forgotten what they learnt in ISSF, due to the term break in between the ISSF and OOAD courses.
- Just by asking students to take a test to assess their competencies from the previous course does not help in improving the competency acquisition.

This led the teaching team to explore the option of targeted blended learning to help students acquire competencies that were not acquired in regular class sessions and also help retain the competencies that were acquired during regular class sessions and thus enhance the overall student performance and retention.

V. PART 2: WITH TARGETED BLENDED LEARNING

A. Process

Figure 4 shows the modified process with targeted blended learning for progression from ISSF to OOAD course, during the academic year 2013-2014. Most of the process is the same except for the introduction of the blended learning during the term break.

The teaching team prepared a set of nine videos that targeted the competencies that were deemed as "not acquired" by the student cohort after the ISSF final exam (see Table III).

TABLE III. VIDEOS FOR BLENDED LEARNING

Competencies Covered by the Videos, Exercises and Quiz	*Tutorial Videos Prepared and posted on You Tube*
C25 and C33	Topic 1: Meaning and various usage of the "null" Java Literal
C22	Topic 2: Constraints and implications of the "final" Java keyword
C8	Topic 3: Pre/post incrementation and decrementation
C8, C13, C16 and C17	Topic 4: Java operators, boolean expressions and loops
C13, C16 and C17	Topic 5: Looping until criteria is met, De Morgan's Law
C27	Topic 6: Simple algorithms such as min, max, etc.
C33	Topic 7: Local and instance variables
C8	Topic 8: Java arithmetic operators
C9	Topic 9: Memory state diagram involving ArrayLists of objects.

Each video also has a set of self-work exercises which the students were expected to work on their own, immediately after watching the video. Additionally, each video is accompanied by a self-quiz comprising of five to ten questions. Students are expected to complete this quiz, with unlimited number of trials without being penalized. Students are expected to view the videos, complete the exercises and quiz, two or three weeks before the semester starts.

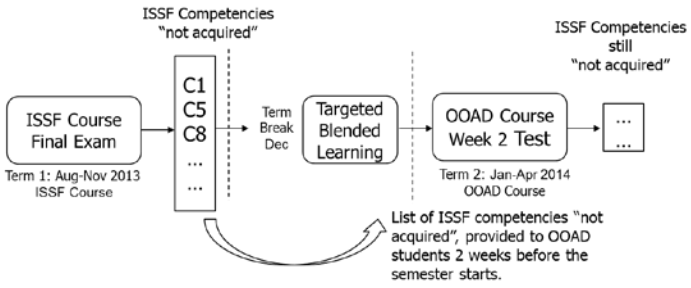


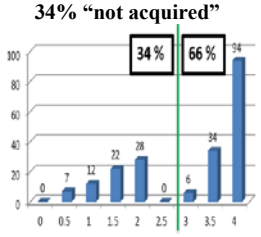
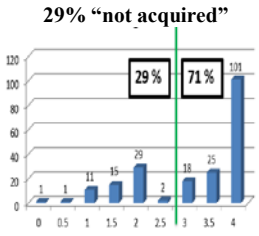
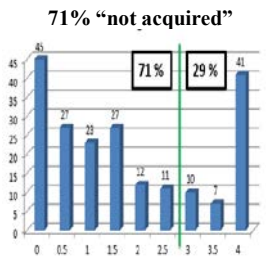
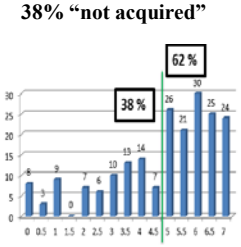
Fig. 4. Process with targeted blended learning

B. Competency Acqusitions Results Analysis

Table IV shows the results that compare the competency acquisition map across the "ISSF Final Exam" and "OOAD "Entry Test" with targeted blended learning. In total in Academic Year 2013-2014, there were 203 students who completed the ISSF course and progressed to the OOAD course.

TABLE IV. COMPARSION OF COMPETENCY ACQUISITION WITHOUT BLENDED LEARNING

Comp. Tested	*ISSF Final Exam* *Competency Acquisition (% of students)*	*OOAD Entry Test* *Competency Acquisition (% of students)*
C25 C33 (Topic 1)	62% "not acquired"	36% "not acquired"
C22 (Topic 2)	44% "not acquired"	1% "not acquired"
C8 C13 C16 C17 (Topic 4)	47% "not acquired"	34% "not acquired"

Comp. Tested	*ISSF Final Exam* *Competency Acquisition (% of students)*	*OOAD Entry Test* *Competency Acquisition (% of students)*
C13 C16 C17 (Topic 5)	34% "not acquired" 	29% "not acquired" 
C9 (Topic 9)	71% "not acquired" 	38% "not acquired" 

As seen from the results shown in Table IV, there has been a substantial improvement in the competency acquisition between the final exam in ISSF and the first test in the OOAD course. Table V shows the percentage improvement in competency acquisition between ISSF Final Exam and OOAD Entry Test for the different topics and the corresponding competencies. Across all competencies there has been an improvement in the percentage of students acquiring the competencies.

TABLE V. PERCENTAGE IMPROVMENT IN COMPETENCY ACQUISITION

Competencies Tested and Corresponding Blended Learning Modules	*Increase in the number of students acquiring the competencies in OOAD entry test compared to ISSF final exam (% of students)*
C25, C33 (Topic 1)	26%
C22 (Topic 2)	43%
C8, C13, C16, C17 (Topic 4)	13%
C13, C16, C17 (Topic 5)	5%
C9 (Topic 9)	33%

The results in Table V shows that the percentage of students who have acquired the competencies shown in the table is higher for OOAD entry test compared to those questions in the final exam of ISSF corresponding to the same set of competencies. This improvement was over a range from 5% higher to 43% higher.

Additionally, referring to Table III and IV, within the same cohort in academic year 2013-2014, we have seen a substantial improvement in competency acquisition.

This leads us to the conclusion that targeted blended learning help students to acquire competencies that were not acquired in regular class sessions and also help retain the competencies that were acquired during regular class sessions and thus enhance the overall student performance and retention. The experiment helps ensure that the students have then acquired the necessary pre-requisites competencies before embarking on OOAD, thus enhancing the overall student performance.

VI. DISCUSSION

The analysis of the results shows that the improvements in competency acquisition are not consistent across all the competencies. For example, referring to Table V, competencies C13, C16, C17, related to topic 5, have a moderate improvement of 5% whereas competency C22 related to topic 2 has a substantial improvement of 43%. We attribute this to the inherent difficulty of some topics and the associated competencies. With the cohort having a spread of very capable to weak students this is expected. This is in alignment with the grade distribution curve for the ISSF course.

One might argue that our results measure competency acquisition across two cohorts. We use cohort in academic year 2012-2013 for experiment without blended learning and academic year 2013-2014 for experiment with targeted blended learning. However, given the range of incoming student capability, the distribution of the capable and weak students' has remained more or less the same across these cohorts. Hence we can conclude that this does not adversely affect the results.

Informal chat with students has also revealed that using the blended learning content students were able to prepare at their own pace, time and place. The most important reason cited was that slow learners could watch the videos several times and practice the exercises multiple times. Additionally, the weaker students could also work at their own pace without the stress of having to complete the exercise within a given time limit. We also observed an improvement in the scores for individual students in these questions as shown in the results summarized in Table VI.

TABLE VI. IMPROVEMENT IN TERMS OF STUDENT NUMBERS

Number of students who performed better in OOAD entry test compared to ISSF final exam	173
Number of students who performed similarly in OOAD entry test compared to ISSF final exam	5
Number of students who did worse in OOAD entry test compared to ISSF final exam	25
Total Number of Students in the Cohort	203

Our approach of competency driven targeted blended learning has been applied for the transition from Year 1, ISSF to OOAD course. Since the results are very encouraging, future work will be aimed towards implementing and evaluating this approach to other academic years, for example, in Year 2, progressing from OOAD to Software Engineering course. Additionally, future work will also be aimed at developing a tool to alleviate the extra effort required in linking

competencies to assessment questions and in conducting a detailed analysis of students' results to derive the competency acquisition map. Currently, though the spread sheet approach works, the tool will facilitate the generalization of the process and help in its implementation across the different courses in the curriculum. This will result in an overall improvement of the teaching and learning in the undergraduate curriculum and therefore, enhance the competency level of the undergraduate students.

Another important challenge is how to motivate students to watch the blended learning videos, do the self-work exercises and self-quizzes especially 2 or 3 weeks before the semester's start. Our approach was to email the students the list of competencies that they need to master along with the URL to the video, lessons and self-work exercises and self-quizzes. Since the videos were uploaded to YouTube, we could not track if students actually viewed. However, we were able to track self-quizzes as they were posted on the School's Learning Management System. The LMS statistics showed that 90% of the students attempted self-quizzes. Hence there was not a major issue with students not doing the work at the end of the break period. Besides the email reminder, this conscientious behaviour could also be attributed to the Asian education culture.

VII. CONCLUSIONS

We studied the problem of competency acquisition when students progress from one course to another and more generally, from one term to next. We observed that some students moved on to a subsequent course (e.g. OOAD) without acquiring some of the competencies in the prior course (e.g. ISSF). This leads to problem in the subsequent course (e.g. OOAD), especially when these competencies are pre-requisites for this. We proposed a targeted blended learning approach to overcome this problem. The blended learning material comprises a set of videos along with hands-on exercises and quizzes, which address the specific set of competencies that were not acquired in the prior course (ISSF).

We evaluated our approach on the batch of students in the academic year 2013-2014 and observed that the targeted blended learning leads to substantial improvements in terms of the percentage of students whose scores went above the threshold which leads the corresponding competencies to be deemed as "mastered". We showed that these results were clearly better than those from the previous batch which did not have the targeted blended learning.

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