Visualizing Cognitive Learning Outcomes of Undergraduates with Cloud-Based Assessment System

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ABSTRACT
Goals and their achievement impact the motivation of students for learning. However, there are contradictory explanations about learning objectives and learning outcomes, which leads to confusion about goals. We advocate the distinction between learning outcomes and objectives and treat them as two different terms. The former is what expected about a student should be able to do, while the latter is what the student actually can do at the end of learning. This paper describes the measurement of the learning outcomes of undergraduates from a lecture session in higher education. A cloud-based evaluation of learning outcomes has been designed. Teachers and students can access the system through a web browser on different devices over the Internet. And visualization of the learning outcomes presents the achievement degree contrasting with learning objectives with a radar chart. The significance of this research is that it helps students understand the learning objectives and their achievements. One of our contributions is to show the relationship between learning objectives and outcomes. Another contribution is presenting a method to motivate students with a visual performance.

Keywords: *Assessment system, Cloud computing, Cognitive, Learning outcomes, Undergraduate, Visualization.*

1. INTRODUCTION

Motivated students work harder and achieve better performance than demotivated ones. When motivated, a student will likely invest more effort and time to attain the goal. Therefore, Universities try to motivate students with all kinds of strategies in higher education. It is essential for generating and sustaining a high level of student motivation. Various factors impact a student's motivation, such as course choice and future ambition [13]. There are two kinds of motivation. One is intrinsic and the other is extrinsic. A student's natural self, family setting, peer pressure, or other surroundings can initiate the student's intrinsic motivation. An intrinsically motivated student will be very focused on details and processes. And an extrinsically motivated student will focus on results and rewards for achievement. Effective learning in the classroom depends on the teacher's ability to maintain the interest that brought students to the course in the first place. Teacher effectiveness is the critical factor that propels student motivation. However, there is little research on visualization of students' learning outcomes to motivate students. Athitaya employed a directed acyclic graph to depict a knowledge structure [12], but visualization of learning outcomes is absent.

In this paper, we tried to visualize the cognitive learning outcomes of students with a cloud-based system. Bloom's cognitive taxonomy is adopted to help instructors design the assessment. This contribution of this paper includes a) providing a mode for teaching to design assessment with the mind of different cognitive levels; b) helping students to understand their achievement and extent to the expected learning outcomes.

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2. LITERATURE REVIEW

2.1. *Learning Outcomes and Motivation*

According to the cognitive motivation theory, goals impact learning [15]. The difference between the current level of performance and the goal motivates a student to work to narrow that gap. And when students see they are making progress toward the goal, they will be more motivated to continue [17]. Therefore, we should help students know the plans and their performance. Both learning objectives and learning outcomes are important factors for students' motivation.

However, there is still a disagreement about what learning outcomes are. Some believe that learning outcomes and learning objectives are interchangeable. For example, Taylor defines learning outcomes as what the learner should be able to do upon successful completion of their learning [18]. However, others advocate there are differences between the two terms. Harden thinks there are five key differences between learning outcomes and objectives and defines the learning outcomes as broad statements of what is attained and assessed at the end of a course [7]. We agree that there are differences between the two terms. We advocate that instructors should discriminate between learning objectives and learning outcomes. Otherwise, it will affect both learning and teaching. For instance, if an instructor treats learning outcomes as learning objectives, the instructor will focus on what to teach and care about the content covered. On the other hand, if a teacher pays attention to the differences between the two terms, the teacher will shift from teaching to learning and emphasize what students attain.

In this paper, learning objectives mean what the student is expected to be able to do at the end of a learning session while learning outcomes are what the student has achieved through the learning session.

2.2. *Cognitive Taxonomy*

There are various categories of learning outcomes from different perspectives. Learning outcomes are defined as a broader set of competencies. Uniform classification of learning outcomes does not exist yet. For example, generic and disciplinary learning outcomes are distinct from each other. General learning outcomes are competencies and skills not related to a specific subject, while disciplinary learning outcomes are associated with the area of a field or discipline [4].

One of the well-known frameworks for classifying student learning outcomes includes the cognitive domain, affective domain, and psychomotor domain [3]. The cognitive field contains learning skills related to mental processes; the affective part involves feeling, emotions, and attitudes; and the psychomotor domain consists of objectives specific to discreet physical functions, reflex actions, and interpretive movements [8].

This paper focuses on the cognitive domain. One reason is that each domain has different levels of learning that range from more basic, low-level learning to more complex, higher-level thinking. It will be complicated to discuss all domains at the same time. Another reason is that the cognitive domain has been more widely discussed than the other two domains. Therefore, we pay attention to one domain. If our method works in the cognitive domain, it will provide a valuable reference for applications in the affective and psychomotor domains.

There are various frameworks for cognitive learning outcome classification. Bloom's taxonomy for the cognitive domain has been adopted in many studies in higher education, such as improving understanding of learning outcomes [6]. With the revised Bloom's taxonomy, cognitive learning outcomes are arranged into two dimensions, which are cognitive process and knowledge; the cognitive process dimension contains six categories: remember, understand, apply, analyze, evaluate, and create; the knowledge dimension comprises four categories: factual, conceptual, procedural, and metacognitive [1].

Another famous learning outcomes taxonomy is Structure of the Observed Learning Outcome (SOLO), primarily applied in measuring student learning outcomes [5]. The SOLO Taxonomy is a system instrument for assessing quality objectively and is also easily understandable by both teacher and student [2]. The framework contains five levels of learning outcomes: pre-structural, uni-structural, multi-structural, relational, and extended abstract. Each of the students' learning outcomes can be classified into one of the five levels.

In our study, we employ the cognitive process dimension from Bloom's taxonomy. Firstly, the six levels including remember, understand, apply, analyze, evaluate, and create help instructors to understand learning objectives should be attributed to different types. Then students can view the goals at different levels. Secondly, we focus on the cognitive process dimension instead of both dimensions to reduce cognitive load for students in the initial stage. It is easy to transfer and extend this visualization to other groups in the knowledge dimension.

2.3. *Cloud Computing*

Cloud computing has been attracting attention from various fields for the past decade. Cloud computing is an information technology service model where computing services are delivered on-demand to customers over a network in a self-service fashion, independent of device and location [11]. Although there is no uniform definition of cloud computing [10], different meanings reflect the typical characteristics of cloud computing [16]. These features include low cost of hardware and maintenance, rich application program interface, on-demand service, up to date, and ultra-large-scale platform [14].

With cloud computing, a user can access computing services over the Internet on different devices from anywhere. Those characteristics allow undergraduates to access the system in the classroom and out of school without any additional software installation. Moreover, students can review the same content from various devices such as mobile phones or tablets. The convenience provided by the cloud-based system leads to the sustainability of student motivation in higher education [13].

3. METHOD AND EXPERIMENT

In this paper, we differentiate learning objectives and outcomes. Learning objectives are what the student is expected to be able to do at the end of a learning session while learning outcomes are what the student has achieved through the learning session. We distinguish learning objectives and learning outcomes to help both the instructor and students understand students may or may not achieve the objectives. By using two terms, we also encourage the teacher and students to rethink if students attain the goals. Therefore, emphasizing the difference motivates both the teacher and students to determine if the students achieve the goals.

There are different levels of learning outcomes in higher education. The program objectives are broad goals while concrete learning outcomes for each course in the curriculum [9]. Usually, learning outcomes from lessons are aggregated and mapped into program learning outcomes. Besides grades, knowledge, and skill tests, other approaches such as self-report and survey are also employed to evaluate learning outcomes [4]. In this study, we focus on the learning objectives from each class or lecture and the corresponding outputs. These learning objectives are designed according to the course objectives determined by the program objectives, as shown in Fig. 1.

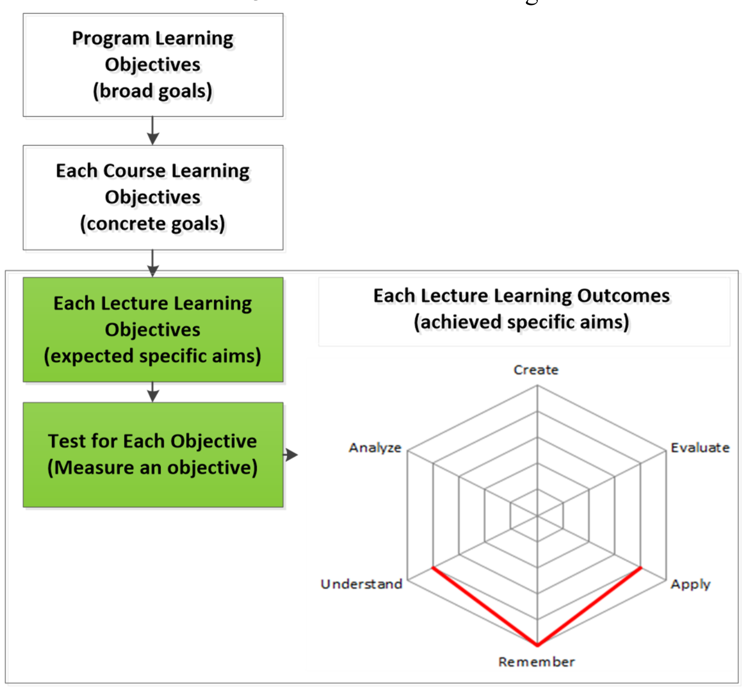

Figure 1: Different types of learning objectives.

The goals are the finest because they are for a single lecture or lab session. Then each aim is classified into one of Bloom's cognitive levels (remember, understand, apply, analyze, evaluate, and create). And tests are designed to measure the extent of achievement of each objective.

The learning outcome of each objective is the achievement degree of a learning objective. A student's learning outcome is calculated according to the following formulation:

$$\mathrm{Outcome}(x) = \sum_{n=1}^{j} \left(\frac{\mathrm{score}_n}{\mathrm{Max}_n}\right) * \mathrm{scale} \qquad (1)$$

Where $\mathrm{Outcome}(x)$ is the learning outcome for the objective x;

Max_n is the max value for the test_n; score_n is the student's grade for the test_n;$n \in [1, j], j \geq 1$ means there is at least one test for each objective; scale is a constant value specified by an instructor. It provides flexibility to display the radar chart. For example, if the teacher assigns 10 to the scale, it means the range for achieving an object is between 0 and 10.

We choose students from the same major to check how this visualization system will affect students' motivation. Students are sophomores from mechanical engineering. These students have been divided into two groups randomly for the C programming course. And there are two instructors for the course. Each instructor teaches the same content at the same time independently. We chose one instructor randomly to adopt our system for each lecture for the course. Upon the completion of the C programming course, we anonymously survey both groups with how much time they spend on the C programming course out of the classroom. There are three critical questions in the survey. The first is about how many days are spent on the C programming course out of the classroom each week. The second question is about how many minutes are spent on the course each time. And the third is about how many minutes are spent totally on the course each week.

4. THE ARCHITECTURE OF THE CLOUD-BASED ASSESSMENT SYSTEM

This cloud-based system is deployed as a Software-as-service model (SaaS). The system is running on a public cloud. Multiple end-users such as instructors, and undergraduates, can access the system through a web browser from different devices, such as a mobile phone, laptop, and tablet. It provides flexibility for end users because it does not require client installation, just a web browser with Internet access available [14].

The cloud service provider is responsible for the infrastructure such as the hardware, the operating system, and the application platform. The application platform includes the web server, application server, and database.

We designed the application composed of models for teachers and functions for students. The architecture of the cloud-based system is shown in Fig. 2.

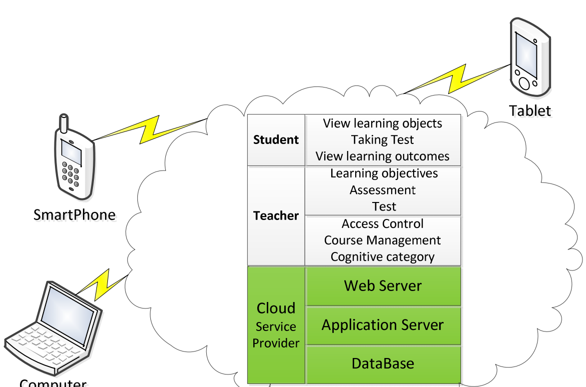

Figure 2: Architecture of the cloud-based system.

Functions for instructors are divided into two parts. One part includes requirements for all courses such as access control, course management, and cognitive category management. The access control provides the configuration about students who can access the system. Instructors set the levels of learning objectives with the cognitive category management module, which allows instructors to adopt different cognitive taxonomies. The course management gives instructors the privileges to add or modify existing courses. The second part contains functions for setting learning objectives, assessment, and test management for a specified class. Teachers can add a learning objective and designate the cognitive level for the goal. Then the system enables instructors to add questions to evaluate students' achievement of the aim. All inquiries go into the question library. Instructors can organize a test by selecting questions from the question library.

The module for students consists of learning objectives reviewing, taking a test, and learning outcomes perceive functions. After instructors publish the learning objectives for a lecture or session, students can view the learning objectives, which help students to know the goals for the class and motivate students to work. Students with granted privilege can take a test to evaluate their learning outcomes after the instructor deploys the test. After that, a student can perceive their own visualized learning outcomes. Visual learning outcomes enable the student to know the gap between the learning objects and their gain, which enhances the student's motivation further.

5. RESULTS

We named the class experimental group where the instructor adopted our system and the other group control group. The results show that each week students from the experimental group (EG, n=17) spent more days (mean=2.47) on the C programming course after classes than students (n=40) did (mean=2.38) in the control group (CG). Students from EG spent more minutes (mean=30.00) each time than students in CG (mean=22.8). Students from EG spend more minutes (mean = 141) each week on the course than the CG group (mean=124). Although there are no significant differences in days of each week and total minutes each week between the EG and CG, the EG had a higher means than the CG.

Moreover, there is a statistical difference in minutes students spent each time on the C programming course between the two groups ($p=0.025$, with two-tailed Mann-Whitney Test).

6. DISCUSSION

This system provides teachers with a convenient tool to design and classify lecture learning outcomes. The system also encourages instructors to rethink low-level and high-level learning objectives. The instructor who applied this system told us learning outcomes and objectives prompted him to think about what students had attained.

With this cloud-based visualization of undergraduates learning outcome system, students can understand the objectives for each class. Students know what they have achieved and the gap between objectives and outcomes. For students who have a large hole, the visual results motivate them to work hard to fill the void. For students who achieve perfect results, the visible effects enhance their confidence and increase their motivation level. This system motivated students to spend more time on the course.

However, this system does not provide visual learning outcomes for a course. One way is to aggregate the learning outcomes of each lecture from the same course and map the results to reflect the learning outcomes of the course. And it calls for more effort. Another method is to design new tests for the course to obtain the course learning outcomes with this system.

In the future, we will work on both methods to visualize the course learning outcomes of an undergraduate.

7. CONCLUSION

We presented a cloud-based assessment system to visualize undergraduate learning outcomes in higher education. The design focuses on cognitive learning outcomes for each lecture. Instructors can set learning objectives for each class and classify every learning outcome into Bloom's taxonomy level. Therefore, it promotes instructors to think student-centered teaching strategies. Students can review the learning objectives and their learning outcomes. Visible goals and outcomes help students consider the gap and motivate students to work hard to achieve the objectives. In the future, we will work on visualizing course learning outcomes based on this research.

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REFERENCES

[1] ANDERSON, L. W. 2014. A taxonomy for learning, teaching, and assessing : a revision of Bloom's, Harlow, Essex, Pearson Education.

[2] BIGGS, J. B. & COLLIS, K. F. 1982. Evaluating the quality of learning: the SOLO taxonomy (Structure of the observed learning outcome), New York, Academic Press.

[3] BLOOM, B. S. 2001. A taxonomy for learning, teaching, and assessing a revision of Bloom's Taxonomy of educational objectives, New York; San Francisco; London (etc), Longman.

[4] CASPERSEN, J., SMEBY, J.-C. & OLAF AAMODT, P. 2017. Measuring Learning Outcomes. European Journal of Education, 52, 20-30.

[5] CHAN, C. C., TSUI, M. S., CHAN, M. Y. C. & HONG, J. H. 2002. Applying the Structure of the Observed Learning Outcomes (SOLO) Taxonomy on Student's Learning Outcomes: An Empirical Study. Assessment & Evaluation in Higher Education, 27, 511-527.

[6] GUMMINENI, M. 2020. Implementing bloom's taxonomy tool for better learning outcomes of plc and robotics course. International Journal of Emerging Technologies in Learning, 15, 184-192.

[7] HARDEN, R. M. 2002. Learning Outcomes and Instructional Objectives: Is There a Difference? Medical Teacher, 24, 151-155.

[8] HOQUE, M. E. 2016. Three domains of learning: Cognitive, affective and psychomotor. The Journal of EFL Education and Research, 2, 45-52.

[9] KESHAVARZ, M. 2011. Measuring Course Learning Outcomes. Journal of Learning Design, 4, 1-9.

[10] MADHAVAIAH, C. & BASHIR, I. 2012. Defining cloud computing in business perspective: A review of research. Metamorphosis, 11, 50-65.

[11] MARSTON, S., LI, Z., BANDYOPADHYAY, S., ZHANG, J. & GHALSASI, A. 2011. Cloud computing—The business perspective. Decision support systems, 51, 176-189.

[12] NITCHOT, A. & GILBERT, L. Visualization of learning outcome structure for self-learning. Journal of Physics: Conference Series, 2020. IOP Publishing, 012012.

[13] NUKPE, P. 2012. Motivation: theory and use in Higher Education. Investigations in university teaching and learning, 8, 11-17.

[14] RANI, D. & RANJAN, R. K. 2014. A comparative study of SaaS, PaaS and IaaS in cloud computing. International Journal of Advanced Research in Computer Science and Software Engineering, 4.

[15] SCHUNK, D. H. & ZIMMERMAN, B. J. 1994. Self-regulation of learning and performance: Issues and educational applications, Lawrence Erlbaum Associates, Inc.

[16] STANOEVSKA-SLABEVA, K. & WOZNIAK, T. 2010. Cloud basics–an introduction to cloud computing. Grid and cloud computing. Springer.

[17] SVINICKI, M. D. 1999. New Directions in Learning and Motivation. New Directions for Teaching and Learning, 5-27.

[18] TAYLOR, R. M. 2009. Defining, constructing and assessing learning outcomes. Revue Scientifique Et Technique-Office International Des Epizooties, 28, 779-788.