

Analyzing Course Competencies: What can Competencies Reveal about the Curriculum?

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Abstract: The application of learning outcomes and competency frameworks have brought better clarity to engineering programs. Several frameworks have been proposed to integrate outcomes and competencies into course design, delivery and assessment. However, in many cases, competencies are course-specific and their overall impact on the curriculum is unknown. Such impact analysis is important for analyzing and improving the curriculum design. Unfortunately, manual analysis is a painstaking process due to large amounts of competencies across the curriculum. In this paper, we propose an automated method to discover their impact on the overall curriculum design. We provide a principled methodology for discovering the impact of courses' competencies using Bloom's Taxonomy and the learning outcomes framework.

Keywords: Competencies, Bloom's taxonomy, curriculum analysis, exploratory data analysis, competency cube, undergraduate information systems program

1. Introduction

Learning outcomes and competencies are employed in numerous education programs for achieving transparency and clarity in course design and delivery (Baumgartner & Shankararaman, 2013). Learning outcomes and competencies are not only beneficial to the teaching professionals for structuring the courses, but also for students to track their skills development.

Curriculum analysis unpacks the components of a curriculum to assess and improve it. The curriculum level analysis of competencies has been studied by (Brabrand & Dahl, 2009; Gnana Singh & Leavline, 2013). Nevertheless, there was no principled approach or framework defined for depth analysis at the overall curriculum level. Several researchers have proposed also frameworks or methods to apply learning outcomes and competencies for evaluating the students (Scott, 2003; Lister & Leaney, 2003), and course design and delivery (Hartel & Foegeding, 2004; Baumgartner & Shankararaman, 2013; Ducrot, et al., 2008; EU, 2014). However, the major drawback of these studies is that, they mainly focus at the course level and in many cases the impact on the overall curriculum level is unknown.

Analysing competencies at curriculum level has several advantages. Firstly, it aids in understanding the overall design of the curriculum in terms of skills progression. Secondly, it helps in discovering any discrepancies, blind spots or gaps in the program, and provides pointers for improving the curriculum. Thirdly, it helps in recommending the competencies for a new course.

Manual analysis of course competencies in a curriculum can be a tedious and painstaking effort due to three main challenges. Firstly, even in a small curriculum, the total number of competencies can reach few hundreds. Secondly, the competencies are verbose in nature and often multiple competencies are combined into a single statement. Thirdly, competencies tend to evolve, especially in technology curriculum where changes happen every two to three years.

In this paper, we propose a framework based on cube models (Khairuddin & Khairuddin, 2008), Bloom's taxonomy (Bloom, et al., 1956), Dreyfus' model of skill development (Dreyfus & Dreyfus 1986) and exploratory data analysis (EDA) (Cook & Swayne, 2007) to discover the impacts of courses' competencies on the curriculum. We evaluated our framework on an undergraduate core curriculum; Bachelor of Science (Information Systems Management) degree program BSc (ISM), offered by the School of Information Systems (SIS), Singapore Management University (SMU). Our results show that the curriculum is designed on both cognitive and progression functionalities.

Additionally, we observe some discrepancies in the curriculum design and propose suggestions for improvements.

The rest of the paper is organized as follows. In Section 2, we study some related work. We give some background Section 3 and Section 4 presents our solution framework. In Section 5, we describe our dataset, present our evaluation results, discussions and we conclude in Section 6.

2. Literature Review

Learning outcomes are statements of a learning achievement and are expressed in terms of what the learner is expected to know, understand and be able to do on completion of the program (Kennedy, et al., 2009). A competency is expressed for individual courses within the curriculum, using a vocabulary of learning outcomes (Kennedy, et al., 2009). For the quality of higher education, learning outcomes are becoming accountable and quality assurance frameworks (Wheeler, 2007). The Qualification Frameworks (EU, 2014) are based on learning outcomes and competencies. In (Ducrot, et al., 2008) paper, the learning outcomes are at the program level and the sub skills (competencies) are specified under them. However, (Hartel & Foegeding, 2004) defined competencies at a higher level than the learning outcomes. In this paper, we use the framework defined by (Ducrot, et al., 2008).

Several learning taxonomies have been recognized as important paradigms in planning and developing educational, training, and professional development curricula (Bloom, et al., 1956; Krathwohl, 2002; O'Neill & Murphy, 2010). Bloom proposed a simpler taxonomy for the cognitive domain, while Biggs' SOLO taxonomy (O'Neill & Murphy, 2010) is more complex and detailed framework. Additionally, to understand the progress of skills learned, Dreyfus proposed a framework, skill development model (Dreyfus & Dreyfus, 1986), which overlaps with Bloom's cognitive domain.

Bloom's taxonomy has been applied in various aspects of learning and education. Examples include, computer science assessments (Scott, 2003), assessing the students based on their ability (Lister & Leaney, 2003), effective course design (Whetten, 2007), curriculum improvement problem (Wheeler, 2007) and generating customized tests (Raykova, et al., 2011). For our solution, we used Bloom's taxonomy to analyse the curriculum on the cognitive functionality and Dreyfus' model of skill development for progression functionality.

3. Background

3.1 Learning Outcomes Framework

Several frameworks have been proposed to integrate the learning outcomes in to the education (Hartel & Foegeding, 2004; Ducrot et al., 2008). In Figure 1 (a), we show the Learning Outcomes Framework implemented (LOF) at the School of Information Systems, Singapore Management University.

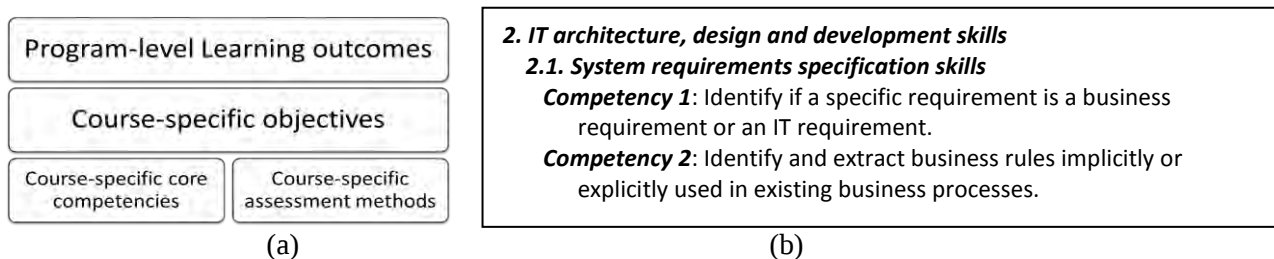


Figure 1. (a) Learning Outcomes Framework. (b) Sample competencies from Y2 course.

LOF consists of three major components: learning outcomes, competencies and assessments. While the learning outcomes have been established at the program level, competencies and assessment are defined at the individual course level. Figure 1 (b) shows an excerpt showing the learning outcome 2 with one of the associated 2nd level learning outcomes and the corresponding competencies for a second year course. For complete list, please refer to (Baumgartner & Shankarara man, 2013) and Ducrot et al., 2008. Though assessments play an important role in curriculum analysis, it is not the focus of our study and we leave it for future works.

3.2 Learning Taxonomies

Bloom's taxonomy divides the learning aspects into three domains; cognitive, affective and psychomotor. Cognitive domain focuses on the thinking level and has been widely applied in several domains including software engineering (Khairuddin & Khairuddin, 2008) and engineering (Gnana Singh & Leavline, 2013). It provides variety of action verbs to write the competencies for a course (Krathwohl, 2002).

In addition to having standard method to facilitate course design and assessment on the cognitive scale, understanding the progressive stages for learning and skill development by individual learners is also important. Dreyfus proposed a skill progression model from awareness to mastery (Dreyfus & Dreyfus, 1986). The skill progression model stages from novice to expert. The three main stages play major role in tracking the progress of the learners; awareness, proficiency and mastery (Judith et al. 2008).

4. Method

In this section, we describe our method to discover the impact of competencies on the curriculum.

4.1 Competency Cube

A competency cube is a conceptual integrated model which integrates the essential elements in design or assessment of learning aspects (Khairuddin & Khairuddin, 2008). Recall that our data consists of three components; learning outcomes (subsumes the competencies), cognitive levels, and skill progression levels. We integrated all these three essential components as shown in Figure 4. Each of the learning outcomes, as depicted on the z-axis of the cube, can be classified in relation to the level of cognitive functioning (see Figure 3, y-axis) as well as each learning outcome can be classified to the specific skill progression level (Dreyfus' model of skill development, x-axis).

The competency cube is similar to data model, where the cube can be sliced and diced across the dimensions to summarize the data. Therefore, when the cube is sliced we can classify the outcomes by cognitive levels and when diced, we can classify the outcomes by progression levels. This cube can be now integrated into a process framework for detailed data analysis.

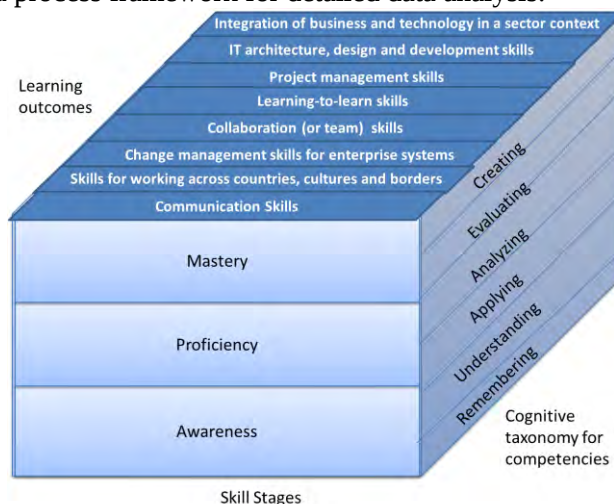


Figure 4. Competency cube – an integrated model of learning outcomes, Bloom's taxonomy and Dreyfus' skill development model

4.2 Automated Curriculum Analysis Framework

We now describe the process framework for curriculum analysis using the competency cube. Figure 5 depicts the sequential process of curriculum analysis framework. Given the full list of competencies expressed by the instructors, in the first stage, the competency cube generates the competencies that are aligned cognitively. To achieve this, Bloom's action verbs (Krathwohl, 2002) are used.

A simple text search is executed on each competency to discover verbs for every cognitive level and the competency is aligned to the corresponding cognitive level. In this process, if multiple verbs are found, the competency is aligned to multiple competencies. For example, “Create and evaluate the business process model for a given real world scenario”, consists of two cognitive functions; *Creating* and *Evaluating*. Therefore, we align the competency to both levels. The competencies will also be categorized and aligned by skills stages - progressively. In the above example, the competency will be aligned to the progression level, “*Mastery*”.

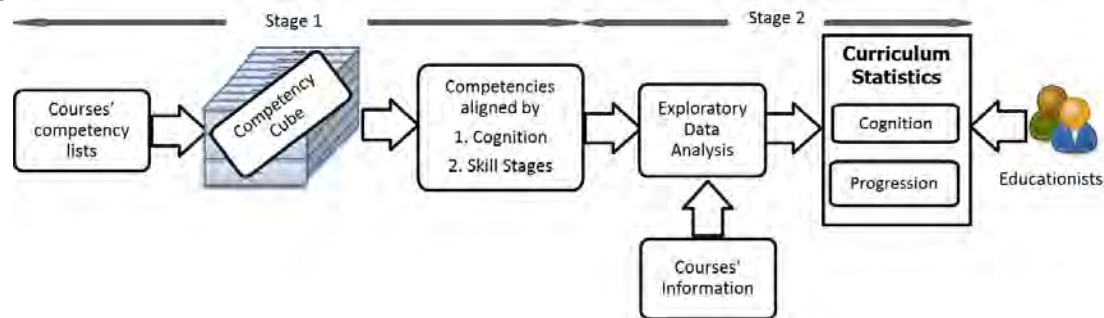


Figure 5. Automated curriculum analysis framework (ACAF)

In the second stage, exploratory data analysis (EDA) (Cook & Swayne, 2007) is executed on the course information (year, term, level, etc.) and on the processed competencies to generate the statistics on the overall curriculum. EDA is useful in summarizing the data using various graphical techniques such as box plots, line graphs, bar graphs, etc. These visuals aid the educationists to analyse the curriculum and make decisions. In summary, cognitive statistics aids in analyzing the curriculum by thinking levels, while skill progression statistics aids in analyzing the curriculum by skill development levels.

5. Experiments

5.1 Dataset

For our experiments we used the undergraduate core curriculum courses from School of Information Systems, Singapore Management University; 14 courses (Year1=4, Year2=6, Year3=4). The course coordinators for each course are required to provide the list of competencies (raw competencies) and map them to program-level learning outcomes. Initially, there were 398 raw competences and after applying the alignment process (Stage 1) discussed in Section 4.2, the total number of aligned competencies increased to 578. All our experiments are based on the processed competencies.

5.2 Cognitive Analysis Results

Recall that applying EDA on competencies which are cognitively aligned yields the curriculum analysis by thinking levels. Figure 6 shows the curriculum cognitive analysis by year.

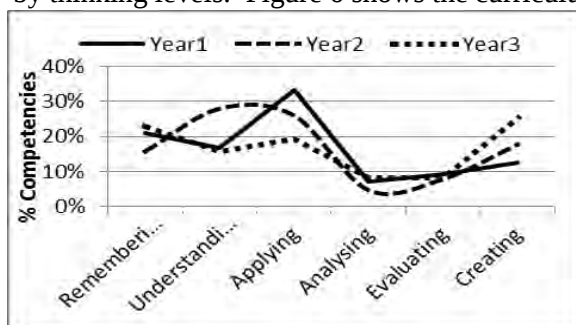


Figure 6. Cognitive: Curriculum analysis by year

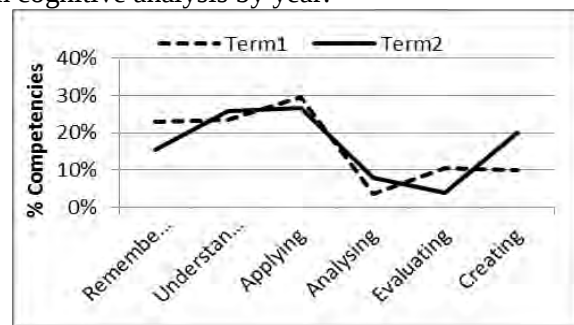


Figure 7. Cognitive: Curriculum analysis by term

We observe that year 1 (Y1) courses majorly focus on remembering and applying. This is because, Y1 courses such as software foundations and data management are technical in nature and are

designed to emphasize learning by application component. Y2 courses majorly focus on understanding and applying. At the same time, they introduce mastery by creating or developing new products. Y3 courses focus on mastery while testing the users' remembering capability. Figure 7 shows the curriculum cognitive analysis by term. We observe that term 1 (T1) courses focus on awareness by remembering and in contrast, term 2 (T2) courses focus on mastery by creating. Both the terms emphasize applying as the curriculum is mainly based on business application of technology.

Next, we evaluate the impact of competencies on curriculum by course level (foundation vs. advanced) as shown in Figure 8. Foundation courses focus on remembering and applying. In contrast, advanced courses focus on mastery by creating. We also observe that advanced courses also emphasize on understanding and applying.

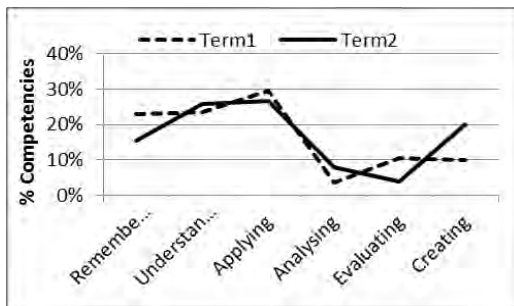


Figure 8. Cognitive: Curriculum analysis by level

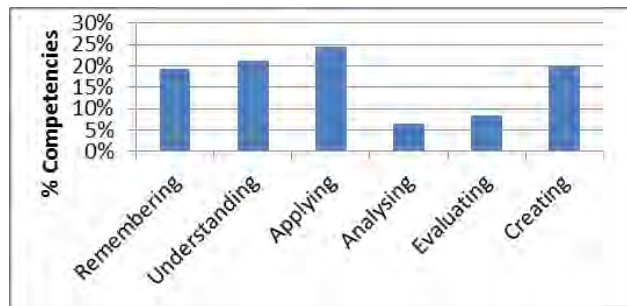


Figure 9. Cognitive: Overall curriculum analysis

Figure 9 shows the average cognitive analysis for curriculum. We observe that, in general the curriculum gives importance to remembering, understanding, applying and creating thinking levels. Evaluating and analyzing components are at a low level, less than 10%. This can be an aspect where the educationist might need to intervene to make decisions on the curriculum design for its improvements.

5.3 Progression Analysis Results

Figure 10 shows the overall curriculum progression analysis. We observed that, proficiency appears to be centered across the curriculum. Mastery appears to be similar to proficiency except for it has lower number of competencies (mean is lower). Awareness has excess variation. Some courses gave major emphasis on awareness while others don't. We observe that, for all years, awareness is given similar importance. However, the focus on proficiency skills decreased from Y1 to Y2. In contrast, focus on mastery skills increased from Y1 to Y2.

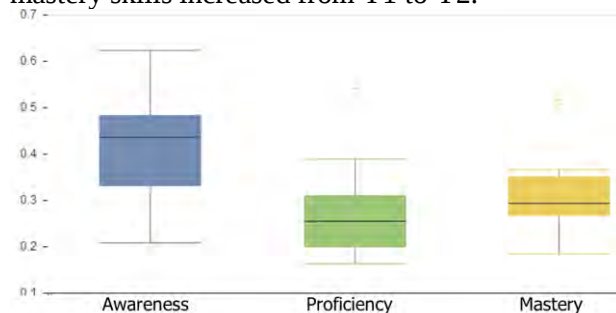


Figure 10. Progression: Overall curriculum analysis

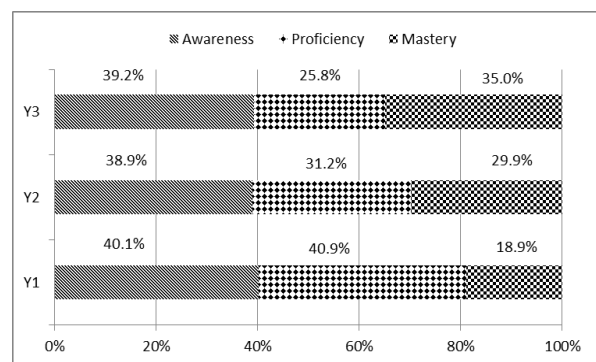


Figure 11: Progression: Curriculum analysis by year

Figure 10 and Figure 11 shows an inconsistent output for awareness. Figure 11 shows that the awareness component is similar for all the years. In contrast, Figure 10 shows that the awareness component has the highest variation.

5.4 Threats to Validity

Curriculum analysis consists of three high level dimensions; design (e.g. course design), impact (e.g. job placements) and policy (e.g. vision). In our paper, we only focused on the design analysis. In

particular we exploited the competencies for the analysis as they are the building blocks for the course design. The results from our experiments on the undergraduate curriculum show the strengths of the curriculum such as balanced cognition levels across the curriculum over the years. At the same time, the experiments identified some of the blind spots in the curriculum such as missing thinking levels for certain courses and low emphasis on evaluation and analyzing across the curriculum. However, the curriculum analysis at the design dimension is incomplete without studying the impact by other course components such as assessments, resources etc., and we leave such analysis for the future studies.

6. Conclusion

Analyzing curriculum is important to not only understand if the current goals are met but also to identify potential problems as early as possible and recommend possible solutions. In this paper, we attempt to analyse an undergraduate core curriculum based on the course competencies. The framework proposed can also be extended to recommendation system where the competencies can be recommended for a new course. In future it is also interesting to study the application of this framework on other curricula. Curriculum analysis is incomplete without analyzing other important components of the curriculum such as course delivery, assessments, resources etc., For example, one can extend the competency cube for assessment analysis and to recommend competencies for new courses.

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