2017/8(2):5-9 desafíos 5

ARTÍCULOS ORIGINALES

Educación

REFRAMING ENGINEERING CURRICULUM BASED ON BLOOM'S TAXONOMY

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ABSTRACT:

This article challenges traditional curriculum at engineering schools in Peru by moving engineering curriculum plans to be reframed based on the amount of concentrated time a learner can spend on a subject without becoming distracted with overloaded schedule by deliberate practice and less lecture rooms, learners gain a compelling expertise before graduation. After digging a little deeper into the student experience, we found the disconnect between what universities teach and the skills needed in the modern society. We have developed an empirical evidence for this estimate hinged on Bloom's taxonomy in a case study at an engineering department. Our result has shown that, on average, 5.5 hours is needed to reach the top level of Bloom's taxonomy immediately after one-hour lecture. From the results of this study and supported by Bloom's taxonomy and the forgetting curve theory, it is concluded that engineering careers need to readjust study plans to concentrate more time on doing, designing, building and developing a particular domain of knowledge and establish tutorial practice for each unit of classroom time with a reasonable workload. Engineering of all strands are always involved with design and building things, hence it requires more tutorials and practical tasks in a specific domain and thus would contribute to a symbiotic relationship between science and technology.

KEYWORDS: Bloom taxonomy, engineering, curriculum reform, Bloom Taxonomy, expectations, school reality, quality of curriculum, curriculum planning, educational innovation, forgetting curve, symbiosis.

INTRODUCTION

Ten thousand hours of deliberate practice to gain mastery in any field! (Colvin 2008). How much time is enough? Is there an optimal number of hours that one should practice after being given a one-hour lecture to master a skill? What does it take to be a successful learner? In Peru, at higher education in engineering, students arrive on campus full of hope that a university engineering degree will improve their lives. In reality this is often uncertain. The quality of engineering education has long been an area of serious concern, but that concern has not yet resulted in any tangible improvement. Engineering colleges still crave for successful and excellent graduates; employers yearn for productive graduates to work for them; parents long for seeing successful children; governments hanker after happy citizens; students themselves pine for having expertise or expert performance in their loved field or particular subject; and most individuals dream of attaining an elite international level in their domain.

Higher education should promote the work skills for life. Nonetheless, learning in many universities still takes place in lecture rooms and rewards the ability to repeat information from lecture notes. The nobel prize winning physicist Carl Wieman revealed that this is one of the most ineffective ways of learning at engineering education in this era (Ballen, Wieman et al., 2017). In addition, in Bloom's taxonomy, knowledge and remembering are placed at the bottom of the pyramid. It is therefore seen as the least important or lowest-level process. It is only the beginning towards more higher-level skills.

In the traditional university model, education signifies delivering information and transmiting knowledge. However, concurring with (Wieman 2014), these days, technology has made it easier for anyone to get information, knowledge and any learning resources. Information was, in the past, scarce but it is now everywhere. It is a unique moment in the history of higher education to rethink the curriculum plan.

In our study case, at information and system engineering school in a challenging five-year academic program, we found the curriculum that includes a wide range of subjects such as system thinking, management, process, language programming, artificial intelligency, math, physics, software engineering, economics, ecology and others. Too much didactic method and pedagogy is concerned merely with the transfer of information. Students have around seven courses a week. They have homeworks in every session a week. We then realize students are mindlessly drifting from homework to homework rather than mastering the skills. Too much workload results in too much distraction and there is no hope in gaining expertise before graduation.

In the next chapter, we describe how much time learners need to gain expertise in a subject contingent on Bloom's taxonomy. The 3rd chapter shows our proposed scheme. The 4th chapter deals with our study results. Finally, the 5th chapter presents our conclusions.

MEASURING LEARNING TIME IN BLOOM'S TAXONOMY

Bloom's taxonomy consists of six levels. A learner starts his learning journey from the bottom level - knowledge - and proceed until he or she achieves the highest level - evaluation. That is, climbing from simply remembering towards more complex cognitive structures at the top.

FIGURE 1. Revised Bloom's Taxonomy based on Anderson & Krathwohl (2001).

As we climb from bottom to top, we are expected to know deeper and deeper the topic of our interest. Therefore, we become an expert once we get the top level.

A prerequisite before we dive into the time measurement is to understand the time we allocated at each level in Bloom's hierarchy. Given a lecture on a topic of interest X or subject X.

At first level, t_1 is the time alloted to remembering knowledge, which measures how much time a learner spends on storing and remembering facts, concepts and terms related to X.

At the second level, t_2 is the time designated to comprehension or understanding so that the learner is able to compare, combine and interprete information in relation to X.

At the third, t_3 measures the time the learner needs to apply his knowledge of X to solve problems in new situations. It implies the answer to the question: How would the learner use what he knows about X to solve problems in a new situation?

At next level, t_4 is the elapsed time for Analysis. At this level the learner identify reasons, causes and evidences to support views and opinions.

At 5th level, t_5 is the time apportioned to Synthesis. At this point, the learner is able to form alternate solutions to X.

At the top level, t_6 represents the time assigned to evaluation.The learner is able to get findings based on evidence. In this level of the taxonomy, the learner is expected to be an expert on the topic X.

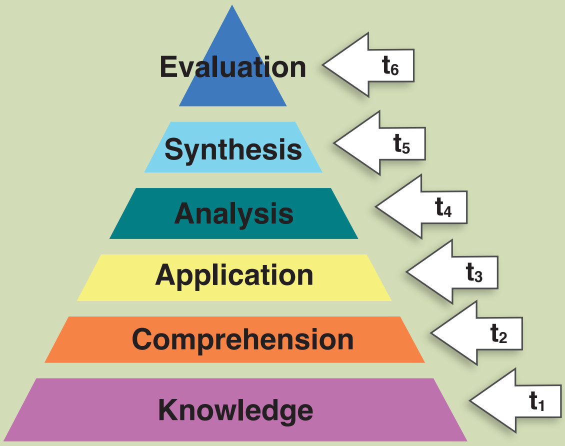

FIGURE 2. Schematic representation of time allocation for Bloom's hierarchical model.

The total time T_X is the time from when the learner started to review the one hour lecture until the student becomes an expert on the topic X.
Hence,

$$T_X = t_1+t_2+t_3+t_4+t_5+t_6$$

Before we can understand the concepts in X, we must remember it. To apply the concepts, we must first understand it. In order to synthesize a concept, we must have analyzed it. To defend our expertise and create an accurate conclusion, we must have completed a thorough evaluation, then we become expert on the topic X .

For this achievement, there is a summon to review and climb the Bloom's taxonomy immediately after lecture. This is supported by the forgetting curve (Murre & Dros 2015). It is suggested to review each lecture immediately afterwards and get to each level of the taxonomy. The longer the learner delays in reviewing the lecture, the less they will remember.

There is an approximation with an exponential curve for the forgetting curve.

$$R= e^{\frac{t}{s}}$$

Where R is retrievability, S is stability of memory and t is time.

2017/8(2):5-9

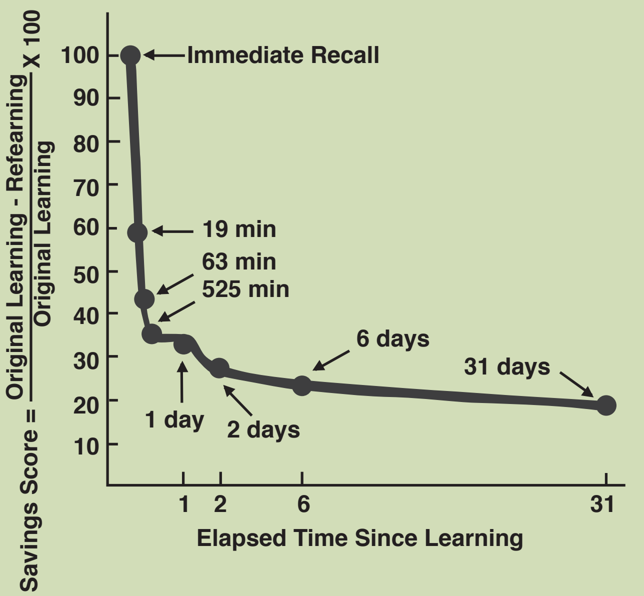

FIGURE 3. Memory experiments of Ebbinghaus examination of forgetting curve replicated by (Murre & Dros 2015).

The figure 3 asserts that information is lost over time when there is no attempt to recall or repeat it. It shows that humans tend to halve their memory of newly learned material in a matter of days. Therefore, there is a serious need to consciously review the learned content. This is a way to move information from short term memory to long term memory.

According to (Murre & Dros 2015) that the best method for increasing the strength of memory is repetition. The stronger the memory, the longer a learner is able to retain the lesson.

From this compelling evidence we have reasons for claiming that schools must select the right workload balance for each subject and concentrate on a particular area of knowledge that leads to a skill mastery.

RESULTS AND DISCUSSION

Applying the measurement

In this section we apply our result from the previous section. In order to measure the time for mastering a particular task, we selected a simplest topic on computer programming as follows:

X= types of loops in Python,continue and breaks

There is sample lecture on the topic X shown by the figure 4.

```
# Prints out 0,1,2,3,4,

count = 0
while True:
    print (count)
    count += 1
    if count >= 5:
        break:

# Prints out only odd numbers - 1,3,5,7,9
for x in range (10):
    # Check if x is even
    if x % 2 == 0:
        continue
    print (x)
```

FIGURE 4. Loops and iteration sample lecture within one hour.

The students were all first-time learners on this topic from the Engineering college.

After a one-hour lecture, we measured time at each level in Bloom's taxonomy for each student and computed the average value of the collected dataset. The result is portrayed in figure 5.

It is evident that t_2 is the highes, correponding to application level. This level is the most natural test for a student's comprehension of what they are studying. This level should be emphasized with tutorials, doing activities and receiving feedback.

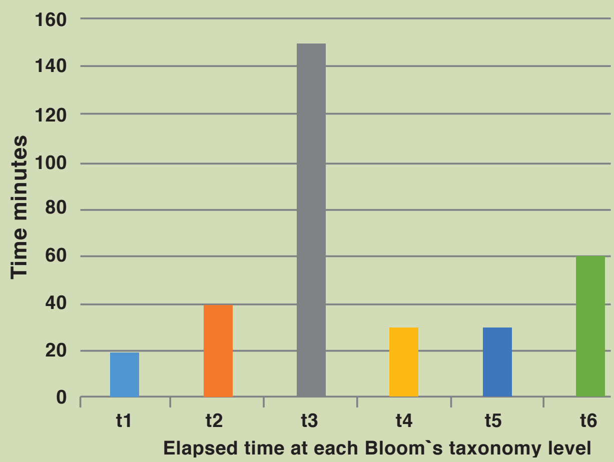

FIGURE 5. Mesurement of time allocation for Bloom's hierarchical model.

From the dataset,

$$T_X = t_1+t_2+t_3+t_4+t_5+t_6$$
$$T_X = 20 +40+150+30+30+ 60$$
$$T_X = 330 \text{ minutes}$$
$$T_X = 5.5 \text{ hours}$$

It reveals that a learner can complete the journey across Bloom's hierarchical model in 5.5 hours to become an expert on the topic X.

This result, leads us to a contentious issue related to student workload. This workload includes both timetabled time at school and non-timetabled student work outside school.

In our study case, we found, on average, six hours per subject per week, around seven hours-lecture per day from Monday to Friday. According to our previous results, for a learner to properly understand and use each lesson, they need seven times 5.5 hours. This is 38.5 hours a day, but the day has only 24 hours!

This observation leads us to suggest a list of student workloads. The table 01, helps to considere the student workload planning for any curriculum reform.

Tabla 1. Timetabled time at school and non-timetabled student workload

1	Attending lecture
2	Having tutorials
3	Having part-time job
4	Traveling to and from university
5	Sleeping
6	Having meals
7	Doing sport and social activities
8	Having private study
9	Cooking, cleaning, washing, snacks
10	Having onversations and discussions
11	Doing group assignment

The table 1 might look imcomplete if we look at other aspect such as the student experience, their technology skills and learning styles. All affect how quickly students can complete a given learning content.

We can also add the fact that students need time for reflection, reflect on what they are learning. It helps them assess what they know, what they don't, integrate new ideas and concepts into their body of knowledge with application to real life situation.

When implementing tutorials students become active experimenters and ensure that learning is relevant to them.

INSIDE SOFTWARE ENGINEERING

In this section we give reasons why engineering needs more tutorial and practical task to reach successfully to the top of Bloom's taxonomy and attain productive graduates.

At its core, software engineering studies ways to build and manage secure computing software that accomplish users' personal, organizational, and societal goals (Pressman 2008). In this regard, there are curriculum recommendations to the rapidly changing landscape of software technology such as ACM (2015).

At university level, in our case study, engineering colleges design a curriculum and implement it in the hope of equiping students for a succesful career in engineering. In time, there is a gap between such expectations and reality.

It takes hours of practice to master a programming skill. To reinforce the correct habits, deliberate practice is an active thoughtful process which involves monitoring learner's performance in real time instead of mindless trial and error.

Community context studies by conducting a survey of the member of society to elicit societal needs have been used to support the reflective practice of curriculum planning committees (Allard et al., 2007). In this survey-based curriculum planning, the content is based on careful, systematic examination of needs (Rasmussen, Hopkins, & Fitzpatrick, 2004). However, there is no sound evidence that learner's workload is being taken into acount when implementing an engineering curriculum. Consequently, curriculum goals do not fit contextual realities. When it is put into practice, the expectations of lecturers, learners and curricular planner crash.

By averring that it is necessary ten thousand hours to become an expert in any field, (Colvin 2008) and (Gladwell 2008) emphasized the vital role practice plays in learning a skill, saying that thoughtful and deliberate practice should be done in a correct way. This claim might be debunked by fellow academics. International Association of Engineers engenieering as application of science and technology dealing with more practical interface for a specific purpose, whether to design a product, process, or medical treatment; to develop a new technology; to construct systems and structures; or to predict the impacts of human action. An emerging consensus is that design is a central practice of engineering it focuses on knowing-how core ideas in engineering. There exist some challenges such as fast evolutions of technology (Mousavifard & Ayoubi 2018).

The implementation of more tutorials for learning in Engineering is related to implicit learning. Evidence suggests, (Dalkir 2017), that implicit learning is more stable and durable over time, it decreases the amount of verbal instruction and verbal feedback as a method.

SYMBIOSIS BETWEEN SCIENCE, TECHNOLOGY AND ENGINEERING

The figure 01 shows the mutualistic relationship between engineering, technology, science and society. It is important for actors at higher education such as students, lecturer, researchers, parents and staffs to understand this symbiotic relationship in which each component viz technology, science, engineering and society benefit from the outcomes of each other. For example, technology is the product of science and engineering. Conversely, scientist and engineers use technology to make further advancement in their domain.
Science is the concerted human effort to understand the natural world or history of natural world by observable evidence.

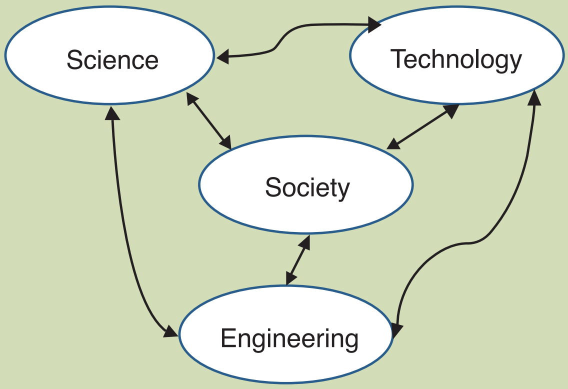

FIGURE 6. Symbiotic relationship between science, technology and engineering.

Technology is the application of science, scientists use the technologies that engineers create to conduct their research. And when engineers start to design a new technology or make an improvement to an existing product, they use science developed by scientists. Hence, engineering, science, and technology influence to each other. They together also influence society, and viceversa. Our human wants, needs, values and problems dictate what problems engineers tackle and what questions scientists address. Furthermore, the technologies change human culture, for example, the impacts of cars, cell phones and internet create new culture and it is a direct result of the influence.

CONCLUSIONS

If universities overload students'schedule with excessive passive listening, they cause stress and strain to them and directly affect the quality of their performance. Hence, they do not reach the top level of Bloom's taxonomy that guarantees the mastery in a subject. The overload schedule becomes a distraction rather than helping the student to be an expert.

Universities need to rethink their approach to curriculum reform if they are to produce people with problem solving skills in specific areas needed for modern life and modern market. It implies the reduction in the number of lectures and focuses on specific areas.
Curriculum planners, with the help of Bloom's taxonomy, must answer the question: How many hours of study per week is best for a university student to master a skill? The lecturer must have a clear view of the intended learning outcomes.

The longer the learner delays reviewing the lecture and climb Bloom's taxonomy, the less succesful they will be. If students do not have the chance to apply new knowledge, it is easy to forget and lose it.

Engineering schools must choose to focus on specific areas such as software Engineering instead of a broad area system and information engineering. This will allow students to develop a deeper understanding of that specific area of knowledge and acquire expertise. In other words, there is a need to develop specialised knowledge and techniques in a subject at undergraduate level.

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