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Just-In-Time Teaching Adds Motivation but Is Less Efficient

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JUST-IN-TIME TEACHING ADDS MOTIVATION BUT IS LESS EFFICIENT

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Abstract

For each major, in addition to directly major-related topics, students also need to learn auxiliary topics – e.g., math topics – which are needed to understand more direct major-related ones. To learn these auxiliary topics, students are required to take some prerequisite math class. The problem is that when the students take these classes, they do not fully understand how these classes are related to their major. As a result, they often lack motivations, do not study well, and this hinders their performance in the follow-up major-related classes. One way to enhance the students' motivation is to use just-in-time teaching, when each part of the auxiliary material is taught exactly when the need for this part appears in a major-related course. This idea definitely increases the students' motivation, but is this the most efficient way to increase their motivation? In this paper, we use a simple mathematical model to show that the traditional approach is more efficient – and thus, other ways of raising students' motivation are desirable.

Keywords*: student motivation, auxiliary vs major-related topics, just-in-time teaching, teaching effectiveness*

JUST-IN-TIME TEACHING: A BRIEF REMINDER

Need for auxiliary classes. A student entering a university selects a major, a discipline that this student is eager to study. This can be biology, this can be computer science, this can be engineering. The student is highly motivated to study courses related to this topic.

The problem is that to properly learn all the necessary material, the student also needs to acquire auxiliary knowledge – e.g., for many disciplines, the student needs to learn several mathematical concepts which are useful for his or her discipline. For example, in engineering and in many biological disciplines, it is important to be able to solve differential equations. In computer science and in genetics, it is important to learn concepts of discrete mathematics. In many disciplines, it is very important to know statistics, etc.

Because of this need, students are required to take the corresponding math classes – which are prerequisites for classes needed for the student's major. For example, discrete mathematics is usually a prerequisite for advanced computer science classes.

Lack of motivation is often a problem. The problem is that when students take these prerequisite classes, they do not clearly understand that these classes are needed for their major. As a result, the students are not sufficiently motivated to study the material presented in these classes – and do not learn as much material as needed. As a result, they are not very well prepared for the following classes in their major – and instructors of these following classes have to waste time repeating this needed but not-well-learned material.

Just-in-time teaching: a possible solution. Just-in-time teaching is a way to avoid this problem. In this approach, the needed auxiliary material is taught not beforehand, but exactly at the time when, in the corresponding major classes, the need to know this auxiliary material becomes very clear. For example, for Computer Science majors at the University of Texas at El Paso, instead of first taking the semester-long class on Discrete Mathematics, students can take part-of-the-semester pieces which are scheduled so as they are taught exactly when the need for discrete structures appears in their computer science classes.

Remaining question. Just-in-time teaching clearly makes students more motivated, but is it an efficient way to make students motivated? This is a question that we will study in this paper.

MATHEMATICAL MODEL OF THE SITUATION

Analysis of the problem. To answer the above question, let us describe this problem in precise terms. We have two choices:

- In the traditional approach, students first take the auxiliary class, in which they learn all the auxiliary material needed in the following classes from their major. Some time passes between the auxiliary class and the moment when this material is needed. During this time, the students forget some of the auxiliary material, so this material has to be refreshed when the need comes to use this auxiliary knowledge.
- In the just-in-time approach, student interrupt the study of their major classes in order to learn the corresponding auxiliary material. In this case, some of the major material will be somewhat forgotten and will need to be refreshed.

The question is: what requires less efforts?

The main difference between the two approaches is that the study of the auxiliary material and the study of the main material are swapped:

- In the traditional approach, we first spend time t to study the auxiliary material, and then time T on study the major-related material. After that, we need some time to refresh the auxiliary material that was studied during time t and which was partly forgotten after time T that elapsed since then.
- In the just-in-time approach, we spend time T on the major-related material, and then spend time t to study the auxiliary material. After that, we need some time to

refresh the major-related material that was studied during time T and which was partly forgotten after time t that elapsed since then.

Let us describe this in precise terms. The amount of the material studied during a certain time is proportional to this time. Let us denote the coefficient of proportionality by c. Thus:

- During time T, the students learn the amount cT.
- During time t, the student learn the amount ct.

How can we describe forgetting? Let x(t) denote the amount of the material that remains t moments after the material is learned. The rate dx/dt of forgetting depends on the current amount of retained information: dx/dt = f(x) for some function f(x) < 0. In the first approximation, we can approximate the function f(x) by the first two terms in its Taylor expansion, i.e., take f(x) = a + bx. For x close to 0, the condition that f(x) is negative implies that a is smaller than or equal to 0. For x = 0, i.e., in the absence of knowledge, the amount cannot decrease any further, so we cannot have a < 0: otherwise, the value x(t) would become negative. Thus, a = 0, and we have f(x) = bx. The condition f(x) < 0 implies that b < 0, i.e., b = --k for some k > 0. O, the forgetting process takes the form dx/dt = --kx.

This differential equation has a known solution: x(t) = x(0) * exp(--kt). So, if we knew the amount x(0) at moment 0, after time t, we forget the proportion

x(0) * (1 – exp(--kt)).

Now, we can estimate how much material is forgotten – and needs to be refreshed – in each of the two approaches:

- In the traditional approach, after learning the amount ct of the auxiliary material, we wait for time T until this material is needed. In this case, the amount of forgotten material is equal to $ct * (1 - \exp(--kT))$.

- In the just-in-time approach, after learning the amount cT of the major-related material, we wait for time t until this material is needed. In this case, the amount of forgotten material is equal to $cT * (1 - \exp(--kt))$.

The more material we forgot, the longer it will take to refresh this material. So, to decide which of the two approaches is more efficient, we need to analyze which of the two formulas leads to the smaller amount of material-to-be-refreshed.

ANALYSIS OF THE MODEL

We need to compare the amounts corresponding to two approaches, i.e., we need to find the relation ? (which can be < or >) between the two above expressions:

$$ct * (1 - \exp(--kT)) \ ?\ cT * (1 - \exp(--kt)).$$

The sign of the inequality does not change if we divide it both sides by three positive numbers c, t, and T. As a result, we get the following equivalent inequality:

$$(1 - \exp(--kT)) / T \ ?\ (1 - \exp(--kt)) / t.$$

On both sides of this inequality, we have the value of the same function

$$F(x) = (1 - \exp(--kx)) / x,$$

but for different values x: for the larger time T corresponding to learning the major-related material and for the smaller time t corresponding to learning the auxiliary material. So, to decide which of the two expressions is larger, we need to know whether the corresponding function $F(x)$ is increasing or decreasing.

According to calculus, whether a function is increasing or decreasing depends on the sign of its derivative dF/dx. In our case, dF/dx = (k * exp(--kx) * x – 1 + exp(--kx)) / x^2. The denominator is always positive, so the sign of the derivative is the same as the sign of the numerator, which has the form (1 + kx) * exp(--kx) – 1. Here, according to Taylor series expansion exp(kx) = 1 + kx + $(kx)^2$ / 2 + … + $(kx)^n$ / n! + …, where all the terms after 1 + kx are positive. Thus, we always have 1 + kx < exp(kx). Multiplying both sides of this inequality by exp(--kx), we conclude that (1 + kx) * exp(--kx) < 1.

Thus, the numerator (1 + kx) * exp(--kx) -- 1 of the derivative dF(x)/dx is always negative. Therefore, the derivative itself is always negative, hence the function F(x) is decreasing: the larger the value x, the smaller the value of the function. In particular, since T > t, we have (1 – exp(--kT)) / T < (1 – exp(--kt)) / t.

We have shown that the relation between these two values is exactly the same as between the corresponding amounts of needed-to-forget material, so we have

ct * (1 – exp(--kT)) < cT* (1 – exp(--kt)).

In other words, the amount of the material needed to be refreshed in the traditional approach is smaller in the traditional approach – and thus, the traditional approach is more efficient.

CONCLUSION

For most majors, to properly learn the major-related material, the students also need to learn some auxiliary material – usually including some math classes. The problem is that by the time the students study this auxiliary material, they do not yet clearly understand why they need to study it. As a result, many of them do not learn it as well as desired.

One of the ways to make student more motivated to study the auxiliary material is just-in-time teaching, when, instead of taking the whole class covering all the needed auxiliary material, this material is divided into chunks, and each chunk is studied only when the students have come to the point at which this particular part of the auxiliary material is needed.

This approach clearly increases the students' motivation, but is it an efficient way to make students more motivated? In this paper, we us a simple mathematical model of the situation to show that the traditional approach is much more efficient. Thus, it is desirable to use other techniques to enhance the students' motivation to study the auxiliary material.

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