A Constructionist Approach for Transitioning to College-Level Mathematics Education

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Abstract. Math phobia is ever present in our society: a significant portion of students find math stressful. This paper describes a constructionist approach to providing support to freshman computer science students studying mathematics. Utilizing the high-level of existing programming knowledge of incoming computer science students at Eötvös Lóránd University, a workshop series is proposed to be offered where the students will learn how they can construct the introductory concepts and techniques of linear algebra using their existing programming knowledge, thereby helping them achieve a deeper, more meaningful understanding of the field.

Keywords: Math education at university level, Math phobia, Constructionism, Constructivism

1 Introduction

Math phobia is the fear of doing math. It can greatly impact the entire life of an individual: "Highly math-anxious individuals are characterized by a strong tendency to avoid math, which ultimately undercuts their math competence and forecloses important career paths. […] Although the causes of math anxiety are undetermined, some teaching styles are implicated as risk factors."[1]

According to the 2012 PISA study[2], about 30% of students have anxiety doing Mathematics. These results describe the *strong* anxiety definition: students actively feel bad while doing math. There is a much wider group of students who simply dislike math without the feeling of helplessness, and thus end up avoiding engaging with it similarly. The result of these self-limiting of Math are adults who are struggling to perform the simplest of calculations, and often react by talking themselves into thinking mathematics is not even important "in the real world".

Math anxiety has been analyzed for a long time. Richardson and Suinn [3] developed a rating scale of Math anxiety back in 1972. Betz[4] analyzed the prevalence of math anxiety in 1978, finding that females and students who had poorer preparation in High School were more math anxious. Four decades later, Khasawneh et. al. [5] performed a scoping review of relevant literature, summarizing findings of the field.

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They found that Math anxiety is prevalent among many disciplines and across multiple countries.

What is the impact of math anxiety and poorer math performance on university studies? Abraham et. al. [6] reviewed literature focusing on college readiness in math. They found that more students were in remedial Math classes than English or Reading. Atuahene and Russel [7] were also investigating American college students' math readiness, and found similarly dire results. DiMartino and Gregorio [8] looking at Italian Math majors found a crisis in transitioning to university level Math studies. Those students who managed to change their attitudes towards mathematics succeeded in transitioning, but those who did not ended up failing. They called on the importance of supporting this transition, focusing on students' feelings and attitudes during the first year. Geisler and Rolka [8] found, that students who consider math to be a series of rules and formulas tend to struggle when transitioning to university. On the other hand, students who view Math as a dynamic field with relevant applications usually succeed.

This paper is a proposed solution to explicitly expressed math phobia by a specific group of students at a specific university. Using a constructionist approach the students can take control of their own understanding of mathematics, with the aim of it reducing the fear and anxiety they experience when learning the material.

2 Constructionist math education for computer science students

In his seminal work Mindstorms[9], Seymour Papert highlighted the opportunity presented by the advent of personal computers. He hoped that the universal appeal of the computer, "the Proteus of machines" will ensure that all children will be enthralled by it. He then hoped to translate this excitement into a general excited view of mathematics and sciences. Noss and Hoyle utilized this concept to teaching mathematics, first by using the LOGO programming language [10], then further developing it into the Microworlds context [11]. The constructionist approach to teaching mathematics integrated the highly approachable Scratch programming language to form Scratch-Math[12]. The idea behind the current project is to re-capture the success of Scratch-Math by re-creating a similar experience for an older group of students.

2.1 Constructing Linear algebra

At Eötvös Lóránd University we are providing the students with an introductory mathematics course during their first semester. The course is made up of roughly half a semester's worth of summary of high school mathematics, but the second half introduces a new area: linear algebra. This proposal is about supporting linear algebra education through a constructionist approach.

The motivation to provide constructionist support comes from interaction with some students in my mentor class. At our university all incoming freshmen are assigned to mentor courses where a student from a higher grade and a mentor instructor meets them weekly to discuss difficulties and solve problems. Most students start the

program having had some experience with programming; in my groups 38 out of 40 said they are comfortable writing code, but the most feared subject they had was mathematics. Yet when we re-contextualized the mathematics topics through the lens of programming (for example, by explaining how formal logic and conditional statements are rather similar, and they can translate one to the other), they reported higher understanding, less fear and greater motivation to work on the math. This proposal is an attempt to create a systemic support system for the study of linear algebra accessible to all interested students instead of the ad-hoc delivery as part of another course, delivering reduced anxiety to a broader group of students.

2.2 Proposed delivery method

The intervention would be delivered as a series of optional workshops provided in a synchronous online manner in the evenings of the fall of 2023. The workshops being optional and an expansion of the course material means that the experiment is low stakes for the students: no student will be worse off by trying out the experience, and can freely discontinue participation. If, on the other hand, this approach would be provided *instead of* the traditional class material, such options would not be possible. Based on student feedback, the online modality and evening delivery ensures that most students can participate in their preferred mode of studying: at home, with their own equipment. This also means that students from different lecture groups can join, possibly addressing a broader audience.

The workshops would be advertised through the mentor classes to reach all incoming freshmen. The first sessions would take place a few weeks before the linear algebra material would start and would focus on familiarizing the students with the Python programming environment we will be using, and representations of numbers, vectors and matrices using the Pandas framework. The workshops then would follow the material weekly, first quickly summarizing the current topic, then leading the students through some programming exercises where they would implement the algorithms discussed during their math class in the programming environment used.

Please note: the student solutions are not expected to be optimal, or even necessarily always correct. Indeed, the programming environment contain solutions to all of the problems the students will be dealing with. The point is, that by re-implementing simple mathematical algorithms on vectors (for example vector addition, subtraction, calculating lengths of vectors, angles between them, dot products, cross products) and then matrices (inverting a matrix, finding the eigenvalues, etc.), the students are constructing functional algorithms – and also constructing a deep understanding of how those mathematical concepts and algorithms work.

The expected results are deeper understanding of linear algebra, a more instinctive understanding of the tools, methods and algorithms, and as a positive side effect, a bit of practice of applied computational thinking.

3 Conclusion

Providing a series of constructionist workshops in mathematics for computer science students at Eötvös Lóránd University has the potential to not only increase their understanding of mathematics and provide them with additional programming practice, but also help them overcome any existing math fear of math. This work continues the work started at Saint Mary's College of California teaching students without any programming background how to move past their fear of quantitative subjects, specifically programming, and become more self-assured, confident and have higher self-efficacy[13]. The author hopes that this approach translated over to mathematics can reverse already developed math phobia, and potentially re-ignite interest not only in mathematics, but also in the more mathematically-based areas of computer science.

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