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A CONSTRUCTIVIST PATHWAY TO REFRESHING MATHEMATICAL UNDERSTANDING

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Abstract

Many people find mathematics hard or even scary. The 2012 PISA report identified that roughly a third of students around the world feel actual panic having to do math -- a ratio that seems to be in line with figures found in the 1970s. The proportion of the population who do not panic from math but still find the subject difficult or unappealing is higher still. The global pandemic and remote education further exacerbated this problem. Meanwhile the world is becoming ever more mathematical and computational, increasing the expected quantitative understanding of the people to meaningfully participate in modern society. These dual effects cause an increasingly widening knowledge and skills gap that need to be addressed at all levels of education. This paper discusses an optional workshop provided for freshmen students before starting university at a small liberal arts school. The purpose of this was to increase mathematical understanding and reduce math anxiety. The approach integrated basic programming skills in the form of block programming with a re-discovering of mathematical thinking. The class started by introducing the creativity of programming, aimed at driving engagement and excitement about the experience. The class then leveraged the simple programming understanding gained at the beginning (especially variables, loops, conditional statements and functional concepts) to re-create basic mathematical concepts, thus connecting the students' interests and majors through block programming and computational thinking to algebraic thinking. The class empowered the students by being able to "create" mathematics, leading to a more integrated understanding. The mathematics content of the course reviewed the key pre-college level quantitative skills, specifically focusing on problem areas that often arise for freshmen university students (function concept, proportions). Utilizing a constructivist approach, the students didn't simply review these topics, instead they re-discovered them through constructing them themselves: a number is just a loop, the basic operations are just loops applied in sequence or embedded in each other, the prime factors of a number are just the previously constructed division operators inside a loop, etc.

Keywords: *Constructivism, mathematics education, programming education, mathematics refresher.*

1. Introduction

This case study discusses a voluntary, three-week long intensive summer mathematics workshop titled Math Success Academy for incoming students at a small liberal arts university in the western United States. The workshop was put together to address specific student needs that arose over time, but its implementation coincided with the arrival of the students who experienced the educational challenges caused by the COVID pandemic.

2. Background and context

The mathematics readiness of university students has been a concern for quite some time, well predating the COVID crisis that caused educational difficulties. It is a problem at that seems be experienced everywhere: at American Universities (Atuahene & Russell, 2016; Bowen, Wilkins, & Ernst, 2019; Harrington, Lloyd, Smolinski, & Shahin, 2016), at American Community Colleges (Abraham, Slate, Saxon, & Barnes, 2014; Cohen & Kelly, 2020; Park, Ngo, & Melguizo, 2021), but also around the world, for example Germany (Büchele & Feudel, 2023), Italy (Di Martino & Gregorio, 2019), Australia (Robinson et al., 2019), South Africa (van der Merwe, Groenewald, Venter, Scrimnger-Christian, & Bolofo, 2020) and the Philippines (Wenceslao, 2022). While a robust mathematics understanding is a key success factor in modern society, this problem is even more critical in study areas where mathematics understanding is expected or required, like the Business and STEM fields. Studies have shown that students entering with

sub-par mathematical skills are struggling to transition in Engineering programs (Bowen et al., 2019; Hieb, Lyle, Ralston, & Chariker, 2015; Moses et al., 2011), Economics programs (Büchele & Feudel, 2023) and even math programs (Di Martino & Gregorio, 2019; Geisler & Rolka, 2021), although GPA and "Calculus readiness" might not be the best indicator to identify at risk students (Pyzdrowski et al., 2013).

Some studies have shown that the students are aware that they are unprepared (Dlouhá, Pospíšil, & Dlouhá, 2022). Universities have been acting on this understanding for quite some time, as a number of them pursued summer "gap-closer" workshops. The results from these attempts were somewhat mixed. (Harrington et al., 2016) found that a free, online summer workshop improved retention and GPA among STEM students, and (Callahan & Garzolini, 2015) report that their summer workshop not only improved retention rates but also increased participation of female students in STEM degrees. (Pierce & Kypuros, 2015) found that offering a summer online course for students who already did pre-calculus but did not qualify for calculus ensured that participants in these programs performed similarly well as students who pre-qualified for calculus. On the other hand, (Hieb et al., 2015) found that introducing a summer algebra readiness workshop for students with low Algebra Readiness Exam (ARE) scores increased their ARE scores, but did not improve the students' performance in the following Engineering Analysis course. (Robinson et al., 2019) found that their summer math workshop increased the students' subjective feeling of preparedness, but they still performed poorer both in terms of completion and grades achieved than traditional students.

3. Description and structure of the Math Success Academy

The quantitative summer workshop was created as an optional experience for the students. The primary concern was to provide extra support to those who felt they needed it, but to not alienate students who felt prepared to start college in the fall. The summer is a relatively "expensive" time for students: many have to work to financially prepare for college, while others are spending a final summer with their families and/or friends before moving away from home, so making this experience mandatory was not considered optimal.

3.1. Modality and timing

The Success Academy was designed to be as unintrusive as possible. It was delivered over 3 weeks, for 4 days a week, in a synchronous online format. The classes were held between 9:15 and 11:45 each morning Monday to Thursday, with a 15-minute break halfway through. This allowed students to work in the afternoons and have two 3-day weekends for travel. The Success Academy was delivered during the three weeks prior to the week of welcome, when the students arrive to the campus and move into the campus housing. This meant that the workshop also provided a gentle on-ramp experience from the freedom of June and July to the brand-new college experience starting in late August.

3.2. Target audience

The primary target audience of the course were the Biology and Pre-med students. These students usually want to pursue graduate education in a medical school, and their interest is primarily in getting access to the healthcare field. Many of them do not have a lot of interest or affinity in quantitative pursuits, yet they have to pass a Calculus class. To support this community, the university created a course called "Applied Math for Scientists", that re-imagined the precalculus material through the lens of science education. The summer workshop primarily aimed to help students transition to this course, but it was open to all interested students. This open access approach proved helpful, since students from all career goals (business, programming, sociology, liberal arts, etc.) participated.

3.3. Goals and needs

The explicit goal of the program was to provide the students with an opportunity to review the relevant material in the hopes of improved performance in math classes. It was, however, further hoped that through the inclusion of accessible programming knowledge the students will gain insight into the fact that math is not something that you memorize, math is something that you do. The academy also wanted to provide the students with the toolset of computational thinking: an understanding that most problems can be solved if they are properly analyzed, deconstructed, algorithmized and verified.

3.4. Success Academy Structure

To achieve the Academy's goals, the workshop was based on the already successful pre-introductory programming courses developed at the university (Magitay-Becht & Das, 2024; Margitay-Becht & Das, 2023). These classes are aimed at students who are somewhat curious about programming, but are too intimidated to take a full-on introductory class. To provide a compassionate,

welcoming introduction to programming, these courses start by utilizing Scratch, developed for middle schoolers. This accessible platform allows the students to overcome their fear of programming, and then the class can gently transition to using more complex and professional frameworks (HTML, CSS, Python, Spreadsheets, etc. depending on the professor and the student interest). Successful completion of these courses gives students a head start in the introductory programming classes, thereby improving their success and increasing their resolve.

For the Math Success Academy, the above structure was changed twofold. Firstly, the advanced topics discussed in the pre-introductory classes were replaced by mathematical content. Secondly, some of the more advanced Scratch topics, like cloning or lists, are introduced on an as-needed basis.

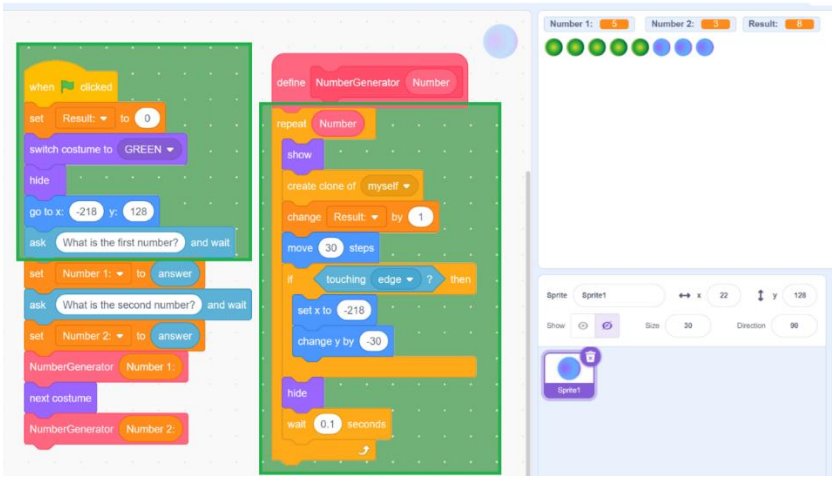
The above changes lead to the following structure (see: Table 1). The first week started with a detailed description of the class, including the constructivist approach utilized; then the students were asked to introduce themselves. As part of this conversation, the students received feedback if the Academy would be useful to them – many hard-working, conscientious students with excellent math skills appeared during this first class; and they were advised to *not* participate, as the material was in preparation for a pre-calculus level college experience. The rest of the week continued with introduction both to programming and (at this point informally) to computational thinking.

Table 1. The structure of the Math Success Academy.

	Monday	Tuesday	Wednesday	Thursday	***Summary***
Week 1	**INTRODUCTION** - Introduction to the course - One-on-one introductions, goal setting for the Academy - pre-assessment	**INTRO TO SCRATCH** - actions - loops - first ever game - multiple threads - design principles 1: prototyping - variables	**SCRATCH CONTINUED** - design principles 2: iterative improvements - branching, conditional statements - logical operators	**COMPUTATIONAL THINKING** - design principles 3: informal introduction to the computational thinking framework - apply it to game design - messages for coordination - repeat until loop	*By the end of the first week, the students are aware of most of the important coding principles and are able to create a game on their own*
Week 2	**BEGINNING OF MATH** - Review - SCRATCH: cloning - MATH: using cloing, discuss the number concept	**THE FOUR BASIC OPERATORS** Using SCRATCH, create animations for: - addition - subtraction - multiplication Discuss operator precedence	**COMPUTATIONAL THINKING** - design principles 4: Formal introduction to computational and design thinking - practice problem: guess the number game - division visualization	**PRIME FACTORIZATION** - primes - lists - program: find a list of prime factors - GCD - LCD	*By the end of the second week, the students were reminded of most of the work from grades 1-7 in math*
Week 3	**NUMBER SYSTEMS** - Review and prime factorization wrap up - Number systems - Converting numbers between number systems	**FUNCTIONS** - function reminder - three ways of describing functions - functions in spreadsheets - functions in Scratch 1: data tables	**GRAPHING A FUNCTION** - design principles reminder: decomposition of the task - math reminder: concept of proportionality - code: create a plotting function	**BRUTE FORCE INVERSE** - "capstone" experience: merging all of programming with all of math - iterative approaches in math - design the brute force inverse approach - Post-assessment	*By the end of the program, the students reviewed all of the material they would need to succeed in Applied Math for Scientists or any introductory Statistics course*

The second week started with a review, as the three-day-long weekend combined with no assigned homework made this prudent. The majority of this week focused on reviewing the first seven years of math, this time through a constructivist lens. The students were asked to re-create the four basic operators using nothing but the freshly introduced number concept and the increment-by-one operator (see Image 1 for an example). The computational and design thinking frameworks were also formally introduced here. The week concluded with prime factorization.

Image 1. The re-implementation of the addition operator using nothing but loops and the concept of increase-by-one.



The final week started with review again and rounded out the prime factorization conversation. A single hour was devoted to the number systems, to expand the students' understanding of the number concept. The rest of the week was devoted to functions, which are usually the biggest hurdle for our students in the pre-calculus classes, statistics classes and economic classes. The course concluded with a mini-capstone experience, where the students integrated their understanding of programming, their understanding of design principles, and their understanding of mathematics to create a brute-force inverse calculating method: using, for example, multiplication paired with repeated trial-and-error (implemented in a loop) to approximate the value of SQRT(2) to an arbitrary level of precision. This final class period was visibly a great a-ha moment for many students, intellectually rewarding them for their perseverance throughout the month.

4. Challenges and Outcomes

The biggest challenge facing the Math Success Academy is the fact that it is an optional opportunity, in the summer. A student needs to be extremely hard-working and be very concerned about their quantitative performance to participate in this experience. A total of 52 students applied to the program, a rather encouraging number. Before the first class period the students' records were reviewed, and students with advanced mathematics background were alerted to the educational level of the workshop. The remaining students were screened a second time during the first class period, which left the program running with 23 students. The workshop was regularly attended for the first two weeks, but for the final week many students had to leave for previously arranged activities (family vacation plans, cruises, etc.) Many of the remaining students were also unable to regularly attend the last week, which strongly undercut the learning outcomes as each class session built very heavily on the one before. Even with these difficulties, however, the program could be considered successful.

First of all, the students' self-reported experience appears to have been positive. 90% of the respondents agreed that they were glad they participated in the program, and 80% said that they liked that programming was part of the experience. A significant majority expressed that programming made understanding math "somewhat" or "greatly" easier.

Furthermore, studying the students' grades in the math classes they took following the summer workshop is also encouraging. Every student who took statistics after completing the program passed the class (although even for people who did not participate in the MSA the fail rate was below 3%). More relevantly, all the MSA students who took calculus passed the class (the fail rate for this course was nearly 18%). In precalculus (failure rate close to 20%), one of the students of the MSA program did not pass their class – but this student had incredibly irregular attendance during the final week of the MSA program (basically missing most of the functional discussion), and they failed most of their other classes in the Fall, not just the precalculus course.

Finally, it is encouraging that a number of students who completed the experience slightly changed their career trajectory and added a programming course or even a computer science certificate to their graduation plans.

5. Limitations

There are several limitations to this report. First of all, the sample size is terribly small. There are only 13 students who took a math class after completing the MSA program, and only 10 filled out the final feedback survey. It is also important to point out that since the program is voluntary, there is a very strong selection bias at play: it is likely that the students who applied tend to be better-performing, harder-working than the average, which might impact the results.

6. Conclusions and next steps

The Math Success Academy effectively introduced the students to the applied concept of computational thinking. This was married with a new-found understanding of programming to reinforce the participant's mathematical knowledge. Most of the respondents of the formal surveys expressed gratitude for this integrative experience – a feedback also shared informally by some.

The author does not claim that the constructivist approach is the only approach or even the best approach for a mathematical refresher. More iterations of the class need to be delivered, and the alumni of the academy need to be followed throughout their academic careers to understand the impact more (for example in the form of a post-graduation final interview). The author, however, believes that this case study is encouraging, and is hoping that this experience will be replicated at other institutions.

References

Abraham, R. A., Slate, J. R., Saxon, D. P., & Barnes, W. (2014). College-Readiness in Math: A Conceptual Analysis of the Literature. *Research and Teaching in Developmental Education*, *30*, 4-34.

Atuahene, F., & Russell, T. A. (2016). Mathematics Readiness of First-Year University Students. *Journal of Developmental Education*, *39*, 12-32.

Bowen, B., Wilkins, J., & Ernst, J. (2019). How Calculus Eligibility and At-Risk Status Relate to Graduation Rate in Engineering Degree Programs. *Journal of STEM Education: Innovations and Research*, *19*. Retrieved from https://www.jstem.org/jstem/index.php/JSTEM/article/view/2310

Büchele, S., & Feudel, F. (2023). Changes in Students' Mathematical Competencies at the Beginning of Higher Education Within the Last Decade at a German University. *International Journal of Science and Mathematics Education*. https://doi.org/10.1007/s10763-022-10350-x

Callahan, J., & Garzolini, J. A. (2015, June 14). *An Elective Mathematics Readiness Initiative for STEM Students*. 26.181.1-26.181.10.

Cohen, R., & Kelly, A. M. (2020). Mathematics as a factor in community college STEM performance, persistence, and degree attainment. *Journal of Research in Science Teaching*, *57*, 279-307.

Di Martino, P., & Gregorio, F. (2019). The Mathematical Crisis in Secondary–Tertiary Transition. *International Journal of Science and Mathematics Education*, *17*, 825-843.

Dlouhá, D., Pospíšil, L., & Dlouhá, K. (2022). High school mathematics knowledge level of technical university students. *8th International Conference on Higher Education Advances (HEAd'22)*. Presented at the Eighth International Conference on Higher Education Advances. Editorial Universitat Politécnica de Valéncia.

Geisler, S., & Rolka, K. (2021). "That Wasn't the Math I Wanted to do!"—Students' Beliefs During the Transition from School to University Mathematics. *International Journal of Science and Mathematics Education*, *19*, 599-618.

Harrington, M. A., Lloyd, A., Smolinski, T., & Shahin, M. (2016). Closing the Gap: First Year Success in College Mathematics at an HBCU. *Journal of the Scholarship of Teaching and Learning*, *16*, 92-106.

Hieb, J. L., Lyle, K. B., Ralston, P. A. S., & Chariker, J. (2015). Predicting performance in a first engineering calculus course: Implications for interventions. *International Journal of Mathematical Education in Science and Technology*, *46*, 40-55.

Magitay-Becht, A., & Das, U. (2024). Pre-Introductory Programming for College Students: Driving Engagement, Motivation, and Creativity to Drive Interest in Computing Studies. *2024 IEEE Frontiers in Education Conference (FIE)*, 1-9.

Margitay-Becht, A., & Das, U. (2023). Enhancing student learning through hidden motivational learning outcomes. In K. Enomoto, R. Wagner, & C. Nygaard (Eds.), *Enhancing student learning outcomes in higher education*. Libri Publishing Ltd.

Moses, L., Hall, C., Wuensch, K., Deurquidi, K., Kauffmann, P., Swart, W., … Dixon, G. (2011). Are Math Readiness and Personality Predictive of First-Year Retention in Engineering? *The Journal of Psychology*, *145*, 229-245.

Park, E. S., Ngo, F., & Melguizo, T. (2021). The Role of Math Misalignment in the Community College STEM Pathway. *Research in Higher Education*, *62*, 403-447.

Pierce, V., & Kypuros, J. (2015). Utilizing an Emporium Course Design to Improve Calculus Readiness of Engineering Students. *2015 ASEE Annual Conference and Exposition Proceedings*, 26.1692.1-26.1692.11. Seattle, Washington: ASEE Conferences.

Pyzdrowski, L. J., Sun, Y., Curtis, R., Miller, D., Winn, G., & Hensel, R. A. M. (2013). Readiness and attitudes as indicators for success in college calculus. *International Journal of Science and Mathematics Education*, *11*, 529-554.

Robinson, C., Galligan, L., Hussain, Z., Abdullah, S., Frederiks, A., & Wandel, A. (2019). *Student Perceptions of Mathematics Readiness from a University Preparatory Program to Undergraduate Studies*. *14*.

van der Merwe, R. L., Groenewald, M. E., Venter, C., Scrimnger-Christian, C., & Bolofo, M. (2020). Relating student perceptions of readiness to student success: A case study of a mathematics module. *Heliyon*, *6*, e05204.

Wenceslao, P. (2022). Mathematical Readiness of Freshmen Engineering Students (K-12 2020 Graduates) in Eastern Visayas in the Philippines. *Asian Journal of University Education*, *18*, 191-204.