Student Success During First Implementations

Robomatter INCORPORATED

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IDEA IN BRIEF

Introducing a new course might seem like a gamble of resources with uncertain added value. Robomatter, Inc. can now reassure hesitant administrators that even first implementations of its courses are approachable by students of diverse backgrounds and those with only novice levels of programming experience. Analyses of student data from thousands of students show that in two different introductory courses, over 80 percent of students scored high enough to earn certification in that subject.

School administrators and other decision-makers are often hesitant to adopt new courses because of the risks involved, even when those courses are part of award-winning curriculum[i], like those designed by Robomatter, Inc. One of the main concerns is that students and teachers, who are unfamiliar with the content and/or the organization of these new courses, will find it difficult to achieve the learning outcomes set forth within the curriculum. This is particularly concerning during initial implementations when value-added assessments might be used to determine whether the adoption of the new course was worthwhile. Courses might be designed with learning science's best practices but that does not guarantee that first implementations of a new course will lead to student success.

Robomatter, Inc. now has student performance data to reassure hesitant administrators that even first implementations are approachable by students of diverse backgrounds and those with only novice levels of programming experience. Analyses of certification data from thousands of students at international schools show that in two different introductory courses (one in STEM robotics and one in STEM computer science), over 80 percent of students scored high enough to earn certification in that subject.

Challenges in the Classroom

Administrators might worry that new courses will not achieve their targeted learning outcomes because of their novelty. That is, teachers and students might not understand how to use the new materials effectively because they are different than what has been done before. Additionally, what it means to have ideal, or even proper, implementations of new courses can vary greatly between curricula, between courses, between school districts, and even between schools. Changes to what were the traditional pedagogy, instructional styles, and activities in classes can all affect how well the new materials are utilized and how successful the outcomes are. With these concerns in mind, Robomatter, Inc. in collaboration with Carnegie Mellon's Robotics Academy consider student and teacher certification rates to be one metric for evaluating the efficacy of implementations.

Robomatter's Approach to Curriculum

Robomatter's courses are designed with consideration paid both to implementation logistics and to the principles of the learning sciences.[ii] Of course, the materials are new and the teacher might be new to teaching computer science, robotics, or programming. Therefore, Robomatter provides training to master teachers, who are then required to pass their own certification exam. When certified, the master teachers can then explain the materials, pedagogy, and implementations to the STEM educators who will then implement our courses and teach the students who will go on to testing for certification. For the two courses currently discussed, that training was delivered online over the course of five days.

With new teachers in mind, our courses are designed to be as turnkey as possible, with ample explanations and recommendations for teachers implementing for the first time: teacher guides, best practices, pedagogical explanations, cognitive learning science explanations, recommended lesson plans, etc.

In introductory courses such as this, we assume that the students are also new to programming, robotics, or open-ended projects. Our learner-centered courses are therefore designed with accessible introductory-level explanations provided directly to students as videos, animations, slideshows, demonstrations, and readings that explain one or more of the following topics: connections to the broader contexts of everyday life, guided instruction necessary to learn new skills and apply newly learned concepts, easy-to-use rubrics that itemize what a project should include and highlight the shared objectives, explanations of how activities and projects connect to the overarching concepts of the course, etc. Students are also guided through initial learning tasks with step-by-step demonstrations of what to do: how to build, how to program, how to test, etc. They are then asked to apply and extend what they have learned by engaging in a range of projects requiring iterative design, computational thinking practices, creativity, and/or innovation.

Ranges of Topics and Performances on the Exam

The certification exams are compiled and administered by the Carnegie Mellon Robotics Academy (CMRA). For the robotics and computer science courses that were investigated in the current analyses, both exams included fifty multiple-choice questions that were selected randomly but proportionately from categories of topics. The threshold for student certification is a score of at least 70.

The majority of questions require students to apply the concepts learned within the course and in that way, the applications of those concepts are more like skills. Those skills reflect students' abilities to think computationally. For example, it is a conceptual understanding to know that sequences are steps to be followed from one action/event to the next in a predetermined order. It is mere recognition to select the option that provides this definition on the exam. But, it is a skill to be able to recognize how to sequence steps, identify the next step(s) in a sequence toward a goal, etc. That set of skills is part of computational thinking practices that are at the foreground of all of Robomatter's courses. Thus, the certification exams assess computational thinking skills as well as content knowledge because students are asked to apply the concepts that they have learned by using their computational thinking skills. They then need to select the answer option that captures the step, process, conclusion, or scenario that they found through applying those skills. This is an important distinction from being asked only to recognize the definitions of concepts as might be the case on traditional multiple-choice exams.

The data collected from 4,329 students who completed the exam for the introductory robotics course, show that 84% of students earned a score at or above 70. Please refer to the table below for a list of the topics included and approximate percentages of exam questions that asked about those topics. To clarify, program flow refers to sequences, repeat loops, conditional decisions, and other features of the program that influence the sequence of behaviors that is carried out. Basic movements include forward and backward moving and point and swing turning. Sensing includes utilizing the touch, gyro, color, and other sensors within programming. All of these topics also highlight computational and algorithmic thinking skills like sequencing, iteration, systems thinking, data, pseudocode, flowcharts, etc.

The data collected from 1,054 students who completed the exam for the introductory computer science course, show that 81% of students earned a score at or above 70. Again, please refer to the table below for a list of the topics included and approximate percentages of exam questions that asked about those topics. The topics included in the introductory computer science course are more specific than those for the robotics course but some of the connected concepts might not be obvious. Variables within programs directly connect to data collection/logging within programs. Conditionals and decisions refer to points in the program when data/conditions have to be assessed (if statements) in order to follow appropriate program plans (if/then statements). Cybersecurity connects to both personal matters of internet safety and larger concerns like hacking. Sandbloqs is block-based programming language software developed by Robomatter, Inc. Functions highlight the use of algorithms for simplifying programs. Object-oriented thinking prepares students for object-oriented programming in the subsequent course. Additionally, within the course, all of these concepts and skills are also tied to computational and algorithmic thinking skills like sequencing steps/behaviors, iterative design processes, systems thinking, pseudocode, flowcharts, etc.

"I think that there are really important things that we have to do with students to get them to succeed in science, to go on and stay with careers. And that includes the idea of being exposed to something. So if you know that those things exist, it makes it easier for you to get involved. For example, it helps to know what an engineer is. It helps to know what a biotechnician is so you're not afraid of it. Then it's experience. When you do hands-on science, you learn to - you learn about electricity by wiring a flashlight. And then it's expectation. And that expectation is we should expect our kids to succeed and to achieve. Children live up or down to our expectations. And so I always call it the three Es - right? - experience, expectation and exposure."

-Mae Carol Jemison, MD

First African-American woman to travel in space (September, 1992; Endeavor)

quoted in an interview with National Public Radio (USA) on February 22, 2017 (http://www.npr.org/templates/transcript/transcript.php?storyId=516695456)

Course	Students Tested	Students Scoring ≥ 70	Percentage Certified
Robotics	4329	3626	83.76%
Computer Science	1054	850	80.64%

Category of Curriculum	Approximate Percentage of Questions
Robotics	
Program flow	50%
Basic movements	30%
Sensing	20%
Computer Science	
Programmed conditionals & decisions	15%
Variables within programs	15%
Sequencing	12%
Cybersecurity	12%
Sandbloqs	9%
Abstraction & functions	8%
General computer science knowledge	8%
Structure & function	7%
Object-oriented thinking	6%
Repeated behaviors	4%
Debugging	4%

About Robomatter

Robomatter Incorporated is a technology and engineering curriculum solutions provider focused on bringing STEM experiences to students by leveraging the motivational effects of computer science and robotics. Robomatter's solutions include research-backed curricula, interactive technology tools, STEM teacher professional development programs, and certification programs through a partnership with Carnegie Mellon's Robotics Academy.

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[i] Robomatter, Inc.'s computer science curriculum has been certified by the New York Academy of Science's Global STEM Alliance (GSA) STEM Education Framework. All certification reviews are performed by a panel of academic experts with deep knowledge related to the subject matter, grade level, and intended audience of the materials under review. Materials that align to the framework receive official certification from the New York Academy of Sciences' Global STEM Alliance, an initiative designed to advance STEM education worldwide. https://robomatter.com/blog-gsa-stem-certification/

Robomatter, Inc.'s robotics curriculum has been certified by the International Technology and Engineering Educators Association (ITEEA), which endorsed the engineering levels of Robomatter's Robotics Curriculum Continuum through its Engineering by Design (EbD) standard, The Engineering Endorsement Matrix. ITEEA's STEM Center for Teaching and Learning has developed the only standards-based national model for grades K-12 that delivers technological literacy in a STEM context. Robomatter is the first organization to attain certification through this rigorous evaluation process. http://www.prnewswire.com/news-releases/robomatters-robotics-curriculum-first-to-be-certified-by-iteea-300404751.html?tc=eml_cleartime

[ii] Course materials and their organization are designed with six principles from the learning sciences in mind:

1) Student-centered instruction
    a. The teacher serves the role as facilitator while students interact with the learning materials and complete projects.
    b. The learning materials provide guidance by breaking down complex concepts and procedures into more manageable parts or steps for the students.
    c. The teacher can further guide activities by checking in on students as they work, and clarifying what needs to be done as needed - if at all.
    d. This could be enhanced and expanded after our courses are in a new LMS that provides hints, tracks progress, etc.

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    - Tobias, S. & Duffy, T.M. (Eds.) (2009). Constructivist theory applied to instruction: Success or failure? New York: Taylor and Francis. ISBN: 0-203-87884-1
2) Differentiated instruction
    a. Students work at their own pace to complete activities.
    b. Project expectations can be adjusted to meet the needs and capabilities of students.
    c. Students requiring additional learning materials to supplement the main activities, can be provided with such in additional resources and/or by the teacher.
    d. Students requiring additional activities to extend and/or enhance the main activities, can be provided with such by the teacher.

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3) Shared learning objectives
    a. The teacher serves the role as facilitator Teachers present the learning objectives to students so that they know what they are expected to do, learn, and accomplish within each activity. There should never be a reason for students to ask the teacher 'Why are we doing this?'
    b. Students will keep those objectives in mind when self-evaluating their own progress through the activity.
    c. Teachers can informally assess the success of the class session or activity by considering how many students reached the objectives.

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4) Deeper learning by doing
    a. Activities focus students on the processes, skills, and their applications instead of on only the concepts involved. This fosters deeper understandings and opportunities for transfer across activities.
    b. The troubleshooting involved in learning-by-doing situations deepens both conceptual and procedural understanding, and critical thinking/resourcefulness as students/teams develop their own solutions to problems.

References:

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5) Contextualization of content
    a. Students recognize how the content and skills are interconnected across activities, and how they function together in order to develop projects, or explain phenomena.
    b. Students recognize real-world applications of the content and skills, which thereby impart value to them and should increase student motivation.

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6) Motivating interactive explanations
    a. Students are asked to explain concepts, skills, applications, etc. to peers within teamwork, or to the entire class along with the teacher during discussions.

b. The explanations provided by students are evaluated by peers or the teacher, who then provide feedback. Often that feedback will require modifying the initial explanation provided.
c. The verbal interactions between members of such discussions will foster deeper, clearer, and more meaningful understandings as they work toward an objective consensus of shared meanings.

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