LearnDeep
MILWAUKEE

Computational Thinking Interviews

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Contents

Summary

The goal of this effort was to understand what teachers and industry mentors need from opportunities for K-12 students to develop computational thinking skills outside of computer science classes. This is based on the recognition that:

- there is a shortage of teachers certified to teach computer science;
- there is a shortage of teachers willing to obtain certification to teach computer science;
- the prerequisites for computer science classes limit the number of students from disadvantaged backgrounds that are able to take advantage of them;
- students often fail to find points of engagement within computer science that are aligned with their interests.

To that end we interviewed teachers working with TEALS, Project GUTS, SHARP Literacy's Design Through Code (DTC) program, as well as industry mentors for the TEALS and FIRST Robotics programs. These interviews focused on the factors that drew teachers and mentors to participate in the programs, and where they have cause for concern.

All of the programs offered something of value to the teachers and mentors we spoke with. What stood out was the ease with which teachers working with Project GUTS recognized the value it could bring to the classroom and their desire to master the tools and enlist their colleagues to use the program to explore topics of mutual interest.

In the report below, we provide an overview of our approach and then walk through what we heard from teachers and mentors. This is captured as a series of forces that push teachers or mentors away from or keep them anchored to current practice, and others that pull them towards, or cause them to shrink back from the possibilities presented by the programs they are now involved with.

Given what we heard over the course of these interviews, we provide a series of recommendations for actions to support teachers and mentors in their work with these programs. In particular we see an opportunity to build a strategy around broad adoption of Project GUTS that is supported by a network of mentors with domain expertise and programs like Design Through Code, which help build students' comfort with block coding tools in earlier grades.

Background

Why concern ourselves with computational thinking skills

Employers in the Milwaukee area recognize a shortage in the talent pipeline. Students are not coming out of high school with the experiences, skills, and dispositions required in the 21st century at a rate and level of diversity sufficient to meet the needs of area employers. This is particularly true in the tech sector, where the issue is compounded by the fact we lose tech talent to other states.

If we are to seriously address the talent gap in tech, students need to engage in work that allows them to understand the wide range of possible careers in the sector and develop the skills that would allow them to succeed in tech industries. This goes way beyond getting more students to take AP Java. And yet, if the only reason we tried to do this was to meet the talent needs of area firms, we would fail to inspire teachers to take on this challenge.

We want to increase the number of Milwaukee area high school students graduating with the skills and experience that allow them to thrive in this economy-- committed learners that can work collaboratively to solve problems. We want to do this not simply to meet the needs of area employers. All students deserve the opportunity to discover something they are passionate about and use it to drive their learning.

We want to increase the diversity of Milwaukee area high school students graduating with these skills. We want to do this not simply because a diverse set of experiences and perspectives leads to better solutions for business. All people deserve a chance to actively participate in the economy and have their talents both recognized and valued.

Finally, we want teachers in Milwaukee area schools who can effectively develop their students as committed learners and collaborative problem solvers. Again, not just because Milwaukee needs a strong pipeline of talent. Developing these qualities in students energizes teachers and gives meaning to their work. All teachers deserve the opportunity to do so.

A way to approach adoption

Solid computational thinking skills[1] are useful across domains and provide a key foundation for the development of tech talent. Efforts to date have emphasized developing these skills within computer science classes. This approach is constrained by a number of factors:

[1] Decomposition: Breaking down data, processes, or problems into smaller, manageable parts;
Pattern Recognition: Observing patterns, trends, and regularities in data
Abstraction: Identifying the general principles that generate these patterns
Algorithm Design: Developing the step by step instructions for solving this and similar problems

- Computer science classes are not widely available, particularly in schools that serve diverse populations.
- Educators certified to teach computer science are in short supply.
- There are limited incentives for teachers to pursue certification and few educators do
- Computer science classes are largely taught at the high school level. If we want to develop strong computational thinking skills among students, they need exposure to and practice with them throughout their elementary and secondary school years.
- A strict focus on computer science as the domain where these skills are developed limits the points of engagement for both students and teachers. As a result, it weeds out both students and teachers whose primary interests lay outside of computer science.

Widespread development of computational thinking (CT) skills will require a different approach -- one that can leverage the interests and passions of both students and teachers in domains outside of computer science.

We look for a bottom up strategy that starts by leveraging the energy of teachers who are passionate about their domain and willing to try new approaches in leading their students. If we want the introduction of computational thinking to spread beyond computer science classrooms, we need to understand what that feels like from the perspective of teachers-- where do they see value, what do they need to help students develop the skills? We need to understand what must be in place for this to be not only an easy choice for teachers but something that drives them to do even more.

Computational thinking concepts are unfamiliar to most teachers. Teachers will need support from industry professionals to understand the concepts, current practices, and potential points of integration. TEALS provides a useful model for how this might be done. In fact, that model of pairing teachers with industry mentors stands to be both easier and more effective here. In this model, the role is to help the teacher and students understand how to apply CT practices within a particular area of study. This likely requires both a lower time commitment from the mentor and is a role much closer to what mentors do on a day to day basis at their place of work than is teaching a computer science class.

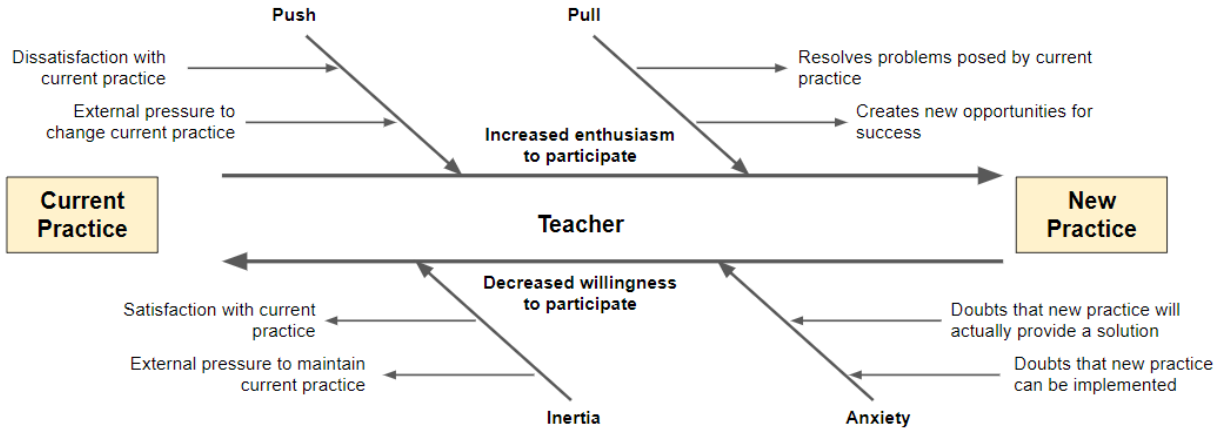
Here too, we need to understand what this looks like from the perspective of industry mentors. What do they need to have in place -- not just allow them to participate, but to do so effectively and see that their work has real value?

The work to understand the needs and concerns of teachers and mentors will be of less value if it is disconnected from existing efforts to develop CT skills. If we start with teachers and mentors that are already engaged, explicitly or not, with bringing computational thinking into the classroom, what we learn can informs not just this effort, but the initiatives already underway.

Finally, we need to use this understanding to help recruit teachers willing to pull computational thinking into their classrooms. We need to develop a pathway not just for them to get better at doing so, but one that can expand the pool of teachers involved. In short, we need to establish a talent pipeline of teachers who understand how to bring computational thinking into the domains they are excited about in ways that deeply engage students. It should also be noted that this will provide a much richer pool of talent from which to recruit teachers for CS classes and certification.

Framing the issues

We use the lens of Jobs to Be Done to understand how educators and their community partners make decisions about where and how to invest their time and energy. Adoption of a useful and effective practice will move no faster than the practice solves a real problem for teachers in the context within which teachers operate. Failure to understand the context within which a teacher might employ a practice and how this practice fits given their other priorities will, at best, slow adoption. At worst, it will lead to active resistance. The same principles hold as we look at how to engage industry mentors to support the work of educators.



We interviewed a total of 11 teachers involved with either MPS's efforts to introduce Project GUTS, SHARP Literacy's *Design Through Code* (DTC) program, or TEALS. The interviews focused on what drew them to participate in the given program, where they see value for themselves or students beyond what they might otherwise use, and factors that drive their willingness to participate. We also conducted interviews with 10 mentors from the FIRST Robotics and TEALS programs. Here too, the focus was on factors that drive their participation.

We were able to sit in on classes using both Project GUTS and DTC. The DTC classes included sessions where we were able to participate as guest reviewers while students presented their final projects. We were also able to observe mentors at work with their FIRST Robotics teams both leading up to and as they participated in the regional competition. This gave us a view into

how students respond to the programs, as well as how teachers and mentors work with students involved in these programs.

What we heard from teachers

The decision to incorporate a new practice in the classroom is driven by a combination of factors. Some tend to push teachers away from what they have been doing and others may pull them towards a new option. Comfort with the current practice and anxiety about a new practice will reduce their willingness to change direction.

Push factors

Teachers identified a number of factors which pushed them away or left them frustrated with the practices they had been using.

Administrative decision

“My administration invited me to a meeting…”

“We were told at the beginning of the school year…”

For our teachers involved with TEALS and DTC, the initial push to participate came from their building administration. The principal or school administration saw value in the program and asked teachers to take on the assignment. This is not to say that the teachers involved with TEALS and DTC did not already have other reasons to move away from their current practice.

Teachers involved with the rollout of Project GUTS at MPS had their interest piqued by the initial email announcement, and volunteered to participate. They did not report a push from building leadership to do so.

Need to expose students to programming

“This is the world kids are going into…”

“I felt it was my responsibility as an educator to at least learn and bring coding to them…”

“I saw the need to pull more computer programming into our science curriculum.”

“I’ve been wanting to do something with coding… I’ll do anything to try and get some [programming] in science and math.”

“[Coding] is something kids need exposure to.”

“This is what companies are looking for…”

Teachers in all three programs had already recognized a need to introduce coding to their students. While they did not use the language of computational thinking, they understand that computer science skills open career paths for their students. They also recognize that computer science skills are something deeper than understanding how to work with word processing or

presentation software. “Coding” is the term they use for what they recognize as an entry point for this larger set of skills.

Outside of the TEALS instructor we spoke with, most had little experience with any type of coding beyond what they have done with code.org as part of an Hour of Code event. This leaves them knowing that they want something, but not entirely sure what that would look like or how they might deliver it.

The desire to introduce students to programming was felt most strongly among teachers working with more disadvantaged students who had fewer opportunities to gain that exposure:

> *“I wanted them to have the same opportunity…”*
>
> *“If we really want these children to have a chance and try [STEM fields] as a career, we have to give them a lot of opportunities across all the curriculum.”*

Cost of materials

“We don’t have a lot of materials here…”

“We try not to spend money out of our own pocket, which is impossible…”

“I [spend my own money] for all of my lessons. It makes you want to come out of science, because [teaching] science is expensive.”

Teachers at both the elementary and middle school level mentioned the cost of materials as an issue when they plan STEM lessons. Where materials are not otherwise available, teachers will purchase materials at their own expense, using their own time to track down low cost supplies. At one school it was reported that materials for STEM projects were in such short supply that some teachers had elected to simply skip STEM lessons rather than continue to pay for materials themselves. These teachers want to provide engaging STEM experiences for the students but are frustrated by the time and financial burden placed on them to provide the materials students will need.

Frustration with current methods for teaching about complex systems

“Before it was mostly all reading and we talk about how it works…”

“A kid won’t pick up a research book and continue reading on their own”

“I had just done [a lab on predator-prey relationships] with paper cutouts...”

Several science teachers introduced to Project GUTS recognized right away that the methods they had been using to teach about complex systems like predator-prey relationships, were less

effective than what might be possible using the models within the Project GUTS curriculum. We did not hear this as a frustration that existed prior to exposure to what they might be able to do with Project GUTS. Rather, once they saw a way to model dynamic systems with software, the tools they had been using seemed inferior.

Need for students to develop collaboration and problem solving skills

“I wrote my Master’s thesis on the 4 Cs, collaboration, communication…”

Teachers recognize that for their students to succeed they need to be able to work collaboratively to solve problems and effectively communicate their ideas. As with the obligation teachers feel to expose their students to coding, many of the teachers we spoke with were uncertain how or where to create opportunities for students to develop this broader set of skills.

One of the teachers we interviewed noted that her students are anxious when their work in other subjects does not match what was modeled in the lesson. She recognizes that her students need to gain comfort with failure as a way to learn, but has struggled to find places where she can help that happen.

Pull factors

Across all three programs, the teachers we spoke with see both an answer to their frustrations with prior practices, as well as additional advantages that, by and large, leave them enthusiastic about participation.

Opportunity to expose students to coding

I was excited. We also use PLTW, Project Lead the Way, in our school, and a lot of times the coding is always the part that gets left out of that because teachers don’t feel comfortable teaching it… So when they said that a teacher was going to come in and teach coding, it was like oh cool!”

“I immediately saw in it computational thinking.”

“I’m not into computer science but I saw the need to pull more computer programming into our science curriculum.”

“The kids need the exposure. We can’t go back to them not having that exposure to computer science.”

“This vision of computer science in every high school, that’s huge, especially in a school like this.“

The teachers involved in all three programs recognized, at the outset, a way to expose their students to coding. This was of particular value for the middle school science teachers using Project GUTS, since without having something that integrates with their science curriculum, there is little time they have with students where this might otherwise occur.

For the TEALS teacher, the program was a way to build the skills of students who might then take more advanced CS classes. The DTC teachers we spoke with saw that the program provides a way for the teachers to gain exposure to coding for their students. This offset some of the frustration they initially may have had when asked to take on another responsibility.

The program fits within the teacher's schedule

In the case of TEALS and DTC, building administration simply made the decision to include the programming and where, in a teacher's schedule, it would be worked in. For Project GUTS teachers, the decision of where and how to pull the curriculum in was left up to the teacher. By the time of our interviews these teachers had already worked out what made the most sense for them.

The most common approach for the teachers we spoke with is to select Project GUTS exercises where they fit into the regular curriculum and offer a more effective way to help students understand a concept. For some this means scaling down a lesson from what the Project GUTS curriculum might include for a given topic.

> *[Once students know how to work with the Project GUTS tools], ...as I need to use it, boom, here's a simulation, it's like a Lab. I just need to pare it down, make it a little more focused.. so it is more feasible for what I'm doing in the classroom.*

We saw the same desire to tailor curriculum to better align with the teacher's goals and where students are in terms of their abilities with the TEALS teacher we spoke with. Teachers in both TEALS and Project GUTS have no interest in blindly implementing curriculum as it is given. They understand what works for their students and their classes and want to leverage their professional expertise to do better for them

With both TEALS and Project GUTS, teachers understand they have the autonomy to tailor their approach. This idea is reinforced in TEALS through the program's on-line tools where teachers may suggest changes to the curriculum and participate in forums where teachers exchange ideas on different approaches. Project GUTS provides similar opportunities for teachers to exchange ideas as well as create and share models for systems outside of the Project GUTS curriculum.

As they strategize about how to incorporate the program, several of the teachers we spoke with have sought to create additional time when students could work with the coding tools. Two of

the Project GUTS teachers mentioned having students work with the tools during their technology block. This provided additional time during the week when students could explore the models they were currently working with. That activity was viewed by both teachers as a better use of the time than what students might otherwise be doing in the block. A third teacher plans to have students use the Project GUTS tools to model problems they take on as part of genius hour projects.

A fourth teacher relies on students in her study hall group to pilot exercises she wants to try in class. Because she sees value in the tools, she's willing to re-prioritize some of the time she has with students to figure out how and when they might best be used. A DTC teacher follows a similar strategy-- she allows groups of students to eat lunch in her classroom so they can have additional time on their projects or with code.org.

In all of these cases teachers' willingness to create opportunities for their students to further engage with the tools is a measure of the value they place on the programs. It also speaks to a desire to use their professional judgement to make the best use of their time with students.

Curriculum aligned with standards

"I was able to cover the standards."

[It was easy to weave into science curriculum because] I was able to cover some of those standards [through Project GUTS]

"Having pre-built curriculum that has lessons complete with rubrics [made it easier to get started]."

For both Project GUTS and TEALS, the fact that the programs provide curricula that are aligned to standards was noted by teachers as a key advantage. For Project GUTS teachers, it makes the curriculum easier to slot in. For our TEALS teacher, it saves him from having to find or build that curiculum himself.

Though SHARP Literacy has aligned DTC with Common Core standards, DTC teachers did not mention a connection to standards as an important part of the program. We assume alignment of standards was important to building administration in the decision to participate.

Provides an opportunity for collaborative problem solving

"This program allows [each student] to have something so different that is still proficient.. [With what we were using before], there really isn't a creation piece like this."

"It wasn't just only about coding. I saw it was like collaborating, communicating, creative thinking... Those skills that they lack."

With DTC, collaborative problem solving is built into the structure of the curriculum. Project GUTS includes curriculum aimed at pair-programming, though only one of the teachers we interviewed had used it. In that case, students worked in pairs not as an intentional opportunity to collaborate, but because the teacher did not have enough laptops for each of her students to work on their own.

Teachers within each of the programs reported that in the course of coding assignments, collaboration between students often rose naturally, with students turning to each other for help. They recognize students' willingness to help each other as positive, both for the classroom culture and as a growth opportunity for students-- *"It's fun to watch the development of even some of the quieter kids"*

More effective method to convey ideas

"I teach ecosystems and the first thing I thought of was is there a way of using [a computer model] for predator-prey relationships."

"The kids could make one little change here and see what happens."

"Here you actually see the model created and how it works out. ... [Prior to Project GUTS], we might talk about how it works but there is no motion."

Several of the science teachers working with Project GUTS reported recognizing right away the value of a tool which allows students to model dynamic systems. The ability to run simulations with different values for key parameters is seen as a far better way of helping students understand how systems function over time.

Further, the ease with which one can tweak parameters in a Project GUTS model and run a new simulation is something difficult to accomplish with physical models:

> *…[W]e're going to do this lab and we're going to do it three times. I never have time to do it three times! But on project GUTS we can do it three times. We could physically model it and they could do it, but if we want to change the numbers we can do it. That was really helpful.*

Within the MPS middle school setting science teachers often cover social studies as well. While the project GUTS curriculum is focused on science, about half the teachers we spoke with had already started thinking about how and where they might pull the tools into social studies lessons. Several went as far as to talk through how they might do so in concert with colleagues who had not been trained in the application. We take this as a strong sign that the teachers recognize that the tools bring real value to their lessons and are already thinking about where else that value can be applied.

Lower out of pocket costs

“When he introduced [Project GUTS] I said I’m interested. I immediately saw it as a cut in my expenses because we don’t always have access to materials”

That SHARP Literacy provides materials for their programming was routinely cited by the teachers we spoke with. Project GUTS teachers noted the potential cost savings over physical lab exercises. Further, both the curriculum and sample models are available at no cost through the Teachers With GUTS website. This has allowed teachers to explore options to pull Project GUTS into their lessons beyond what they may have explored during training sessions.

Block coding environment is easy for most students to pick up

“I’m amazed by how quickly the kids pick it up.”

“Some of them just jumped on and made their own game already.”

“This kids are so electronically advanced that if you don’t get it they will figure it out. They’ll work it out and they will help each other.”

DTC teachers reported that many of their students had already been exposed to code.org, Scratch, or Snap!, most often through the Hour of Code program. The block style programming is easy for students to pick up, and while the coding tasks get more complex over the school year, by and large, students are willing to take on the challenges.

Project GUTS curriculum uses the StarLogo Nova block programming environment designed to model dynamic systems. The environment is familiar enough to students who have already been exposed to block programming through code.org, that most are comfortable diving in.

Students who have not had the prior coding experience do have more of a struggle with Project GUTS. In addition to learning their way around the coding environment, students need to understand the agent-based programming model of StarLogo Nova

Most of the teachers we spoke with reported that at least some students in their classes had gained enough comfort that they were experimenting with StarNova Logo outside of the assigned work.

Training and support were sufficient to move forward

In the same way that the block programming environment of code.org provides an easy onramp for students, it has also provided an onramp for the MPS science teachers using Project GUTS, most of whom have limited experience with any type of programming.

Among the Project GUTS teachers we talked with, all were able to come out of the training sessions provided by MPS confident that they could at least try a lesson with their students. While teachers would like more time to understand how to build models within Start Nova Logo, they did not view gaining comfort and mastery with the tool as beyond their abilities. When teachers talked about the support they would like to have, it was focused on helping them understand how to effectively model systems they wanted to explore with their students.

Within MPS, the Project GUTS rollout has been coordinated by a science curriculum specialist at the central office. The teachers we spoke with routinely noted his willingness to provide ongoing support should they have questions. Though not all had reached out for help, knowing that support was available left them more confident that they could successfully make use of Project GUTS.

The TEALS teacher we spoke with had a similar perspective-- both the initial training and ongoing support of TEALs mentors leaves him confident in moving forward.

Participation allows me to be part of the solution

“We know there are so many situations where there are buildings, or classrooms, or teaching resources or things like that where individuals are not getting access… so being part of that [solution is important to me]. I can’t do anything elsewhere, but I can do something here.”

For each of the three programs, teachers view participation as a way they can help address the need they see to expose students to both computer science and problem solving. The structure and support within each program saves the teacher from having to find or create something on their own, and feels more meaningful than other options they have exercised, such as participating in Hour of Code events.

Secondary benefits

In addition to the factors which initially drew them to participation, DTC and Project GUTS teachers noted additional benefits of the programs. For the most part, these benefits were not recognized until the teacher had been in the program for some period of time. While these factors did not influence the teacher’s initial decision to participate, they now contribute strongly to teachers’ enthusiasm to continue the work.

Student engagement

“Kids respond differently when there is a computer in front of them. ...They don’t want you standing in front of them talking.”

“I’m really impressed by how the kids are responding to it. They are jumping right in.”

“For everything I do there is always one or two [kids off task], but not with this stuff.”

While a couple of teachers mentioned they suspected students would find coding engaging, they were pleased to see high levels of engagement with both DTC and Project GUTS. Several teachers recounted stories of students who might otherwise prefer not to stand out, step up into roles where they would help other students with coding challenges.

An opportunity for students to create

Both DTC and Project GUTS teachers mentioned that the opportunity for students to create something is a key driver of engagement.

> *“Oh, can we create something, can we create art with code. It was those skills that I saw this really help”*
>
> *“[With Project GUTS] there’s more of the creation piece… they get to make something out of these blocks… With textbook problems, there really isn’t the creation piece like this. ”*

We had the chance to talk with students as they presented their final projects within DTC which involved designing a solution to a problem they identified at school. For many of these students the coding portion of the presentation, in which students assembled code blocks to produce a simple rendering of their solution, took a back seat to the physical models they built. Nonetheless, their enthusiasm for having had a chance to investigate a problem and build a physical model of a solution they created was clear to see.

Aside from freelance activities to build games within StarLogo Nova, the creation opportunities for Project GUTS students are centered on developing the models they use to investigate the system under study. Teachers recognize the value for their students in letting them develop these solutions, and several made note of their own efforts to step back from telling the students what to do so that this may happen: “*I can stand back, the facilitator is a better position for the teacher.”*

Unplugged exercises as an opportunity to build classroom culture

“That whole hands-on movement, that’s really powerful for them.”

“I loved those [unplugged activities]. I’m going to put that at the beginning of the year.. It was like team building, that’s how I treated it”

Project GUTS curriculum includes “unplugged” exercises in which, prior to coding, students physically simulate the behavior of agents in the system they will model. One of these, the *Walk & Turn* exercise was used by several of the teachers. In this exercise, students form a circle spaced some distance apart. They are then asked to predict what will happen if they all “Turn to face the person on your right while keeping this heading, take three steps.”

One of the teachers found that this type of activity, in which students are up and moving, discuss ideas, and work collaboratively to discover how a simple set of rules can result in complex, emergent behavior is also a great team building exercise. She prefers the unplugged activities to what she had used at the start of the year, since these exercises are directly tied to learning objectives. After going through this first unplugged exercise, she recognized that she could front-load several Project GUTS lessons at the start of the year, as a way not just to get students up to speed on the tools, but to build a positive classroom culture.

Competent help in the classroom frees the teacher to do more

“It was nice to switch rolls... not be the teacher, and go help the kids that were struggling more. ...[With 31 kids in the class], I can never do that.”

One of the DTC teachers noted that the SHARP instructor’s ability to effectively lead the classroom gave her time to step back, observe students, and guide work with those most in need of help-- something she rarely has the chance to do. This opportunity is created because the SHARP instructor knows how to lead a classroom and engage with students, and the classroom teacher trusts her ability to do so. This is further aided by the fact that the SHARP instructor comes on a regular basis and has been able to build a solid relationship with the students.

For this classroom teacher, the opportunity to step back from managing a classroom of 31 students and devote time to those most in need of help is a welcome relief that leaves her feeling much more effective as a teacher.

Project GUTS models expose students’ thinking

Science teachers using Project GUTS as an alternative to physical models of dynamic systems recognized another key advantage. Since the Project GUTS models students develop are captured in code and can be saved off at any point in time, the teacher can step through both their thinking and execution of a model when the behavior of the system is not what one would expect.

In contrast, it is often difficult for both teachers and students to reconstruct where and why things went awry when the results of a physical model didn’t match what might be expected. Did

the student not follow a procedure, was there an error in recording data from a prior state of the model, etc.

Teachers using Project GUTS often found that students would change not just the parameters of their models, but aspects of the model itself. This gives students a chance to quickly see how different assumptions about how a system functions can result in different behavior of that system As noted above, this is something there is seldom time for with exercises which use physical models of systems.

One teacher also noted that because students' thinking is captured in code, it facilitates conversations that might not otherwise come up-- they can see how another student's solution might require fewer lines of code and will talk through the logic of their different solutions. As this teacher noted, *"...the interactions of students, the sharing of ideas, are almost more adult."*

DTC's MIAD visit inspires teachers and students

"They got to meet people who already [in the design field] and learn what they went through to get there.That was amazing because when they saw [the work MIAD students] had done, it made sense to them [as something they would love to do too]."

Several of the DTC teachers note the class visit to MIAD's Open Lab as one of the program's highlights. The visit gave both teachers and students a chance to see design thinking applied across a variety of domains, the technology used to support that work, and how product development works in the real world.

One of the teachers we spoke with noted another realization having had the chance to meet MIAD students and faculty. It was clear to her that she could benefit from having a chance to work with design professionals over the summer to better understand the design thinking process. She works to play an active part in her classroom during DTC sessions, and that would allow her to do so in a more effective way.

Inertia

Teachers noted two related issues that slow wider use of Project GUTS within their classroom or school.

Cognitive overhead/ time required to get comfortable with the tools

"I know my colleagues well and they would not have wanted to take on the extra challenge..."

“The feeling here of overwhelmingness amongst the staff, considering our to-do list, I would be afraid to share [with colleagues]... When I would share [another program I was excited about] they would say ‘I don’t have time for that’... My colleagues are resistant to adding to the pile.”

As a self selected group, the teachers who chose to participate in Project GUTS were willing to spend a bit of time to take on a new challenge. As one teacher, quoted above noted, not all of her colleagues are in a position to do so. To the extent that teachers are dealing with classroom management issues, new curriculum, or other initiatives within their school, they have both less time during the day, and less cognitive overhead to take on a new task.

The extra time that these programs might require of the teachers was not noted as a hurdle when they chose to participate or accepted the request to do so. However, as hopeful as they are for the program, all of the Project GUTS teachers expressed concerns about finding time to understand how they could most effectively use the tools. They see the value, they know they need to build their skills and experience to take full advantage of the possibilities, but they are still trying to figure out when and how they could do that. Most spoke of vague hopes to “poke around over the summer”, or “get together with a colleague at some point”.

At this point, the lack of time when teachers have the energy and motivation to dive deeper into Project GUTS is not a barrier to its use, but one can see how it delays making fuller use of the tools. Given what we’ve heard, it’s also easy to see a scenario where a new initiative from the district that causes a shift in focus for the teachers could delay the expertise they aspire to gain even further.

A lack of cognitive overhead to take on a new practice and the free time required to get up to speed are likely to be barriers to adoption for other teachers who might, in different circumstances, see value in program.

Anxiety

All of the teachers we spoke with look forward to continued involvement with the programs. this comes in spite of factors that cause some bit of anxiety for several of the teachers we spoke with.

Lack of programming experience

“The overwhelming piece was that it was such a short amount of time that we got training and I don’t have a lot of time to play and explore myself. I’d like to repeat the task as a student so I understand where the misconceptions will be... That was tough for me.”

“For me not knowing a lot about computers it is a tough program to learn and I have to keep up with it to teach on it. I’m going to need more training.”

“This whole coding thing is completely new for me.”

“I would love to go visit another school, their comfort level seemed way higher than mine.”

The primary anxiety we heard was from teachers working with Project GUTS was centered on their lack of experience with both programming and modeling dynamic systems. This concern came from a couple of different perspectives. Some teachers wanted greater comfort and understanding with the programming tools so they would be in a better position to help their students when they ran into problems. For these teachers it wasn’t so much that they want to be able to provide the answers to students, but that they could more easily find the right set of questions that would lead a student to success.

The larger concern teachers had was that their lack of coding experience made it more difficult to try out or develop the models they wanted to introduce to their class. Several of the teachers indicated that they feel most prepared to teach when they have walked through the exercises themselves first. Here they look for support so they can be more effective in their preparation for class. The inability to get to the point where they would like to be with Project GUTS is a source of frustration for some: *“[When I can’t fit Project GUTS in] it’s frustrating because I’ve invested time...in going to training.”*

At least a couple of the teachers opted to leverage their lack of experience to draw more from their students-- *“let’s figure this out together…”.* However, even they had concerns about their level of comfort with the tools. Others we spoke with were simply unwilling to put themselves in this role.

This seems too gamey

“[Project GUTS] is viewed as gaming. In fact the administration here wasn’t as supportive. I took it to one of my PLCs (Professional Learning Communities) for the science department, and they saw it as games.”

Some of the teachers involved with both DTC and Project GUTS expressed a concern of theirs or their colleagues’ that the coding exercises used within DTC or the visual output of StarLogo Nova within Project GUTS was too much like a video game. The Project GUTS teacher quoted above recognizes the value of being to run simulations, but also that there is work to be done to change the perceptions of others within her building.

We need to make sure students use equipment appropriately

“... they took advantage of being on the computer and some of them were doing inappropriate things, so I took them out of the program.”

“Their respect for the equipment is a big deal. If they just pound on the keys I can’t let them use that tool.”

A few of the teachers mentioned that their willingness to get students engaged in work on computers is tempered by how they see students treating the equipment or what students spend their time doing on a chromebook when they have one in class. For at least a couple of the teachers we spoke with, inappropriate use of computers in the class prompted teachers to discontinue use of Project Guts for some students or consider not using the program within a given lesson.

Coding exercise does not support the larger learning objective

The DTC teachers we interviewed teach 4th grade or combined 4th and 5th grade classes. For the final project within SHARP’s 4th grade program, students work in teams to identify a problem at school, sketch a solution, and use simple materials to build a prototype. As part of this effort, students are also asked to use the block programming environment of code.org to create an illustration of their prototype.

While teachers report that students enjoyed earlier coding exercises and were very excited to work on their prototypes, many students were frustrated by the task of using code to create an illustration.[2] This came through in a number of the project presentations we sat in on, where students seemed to have little interest or pride in the illustration produced through code. Their focus and excitement was centered on the physical prototypes they had produced.

We noted, as has SHARP, that using commands to draw lines within code.org is a painfully slow process of illustration that is awkward for students. As one of the DTC teachers pointed out:

> *You have to work on simple things before you can make something more complicated. You can’t go into code and make a complicated rendering if you haven’t had practice doing simpler things.*

The difficulty students have trying to create an illustration with code prevents them from using the exercise as a tool to aid their thinking about their solution. One can contrast this with the model building exercises within Project GUTS where creation of the model itself helps the student understand the system under study.

When asked about the role the coding exercise played in developing her team’s solution, one student reported that it was not much of a factor at all. Her face then lit up as she noted, *“..but last year [In SHARP’s program] we used code to create the art that is hanging upstairs.”*

[2] Students would use code blocks to position a pen, set a direction and distance for the pen to move. This process was repeated for each line used to illustrate their prototype.

What we heard from mentors

Above, we looked at teachers' concerns around incorporation of a new practice in the classroom. For mentors, the parallel is a decision about how they will spend their time. Here too we can look at the same types of forces -- push, pull, interia, and anxiety.

Push factors

For the mentors we spoke with, the push factors largely come from intrinsic motivation. While mentors noted that their employers encouraged participation, none that we spoke with reported pressure to participate.

I want to give back

"My thought was, … I want to give back

"...to give a little something back"

"I had this desire once before because [disadvantaged students] need more help."

Most of the mentors we spoke with listed a chance to "give back" as the primary driver for participation. That drive has tended to push these mentors to work with schools with larger populations of disadvantaged students. As one mentor noted, *"The kids at [a wealthy suburban] high school, they have plenty of resources, those kids have plenty of advantages."*

First Robotics teams often end up recruiting mentors from among the parents of students participating in the program. One of our mentors took this route into the program at the suburban school his children attended. While he still mentors a team there, the desire to give back drives his engagement with another team at an MPS high school.

For several of the mentors we interviewed, the desire to give back was tied to the joy they find in the work and the experiences they had which led them to their careers. In a thread of conversation around helping students develop a passion for software development, one mentor noted:

> *"If someone wasn't paying you to do this, and you weren't doing this for school, would you still be doing it? In my case, the answer is yes."*

Reflecting on what excites him about work as a TEALs mentor, another noted:

> *"I wouldn't be where I am now and doing what I do today if I had not been touched early on in high school."*

We need to develop tech talent

“There is a shortage of developers available in the US, you hear this all the time… If you are looking for good jobs for people, this is something to train them in.”

“We have hundreds of programmable controllers at our plants, [we need] people who can program those devices…”

Both TEALS and FIRST Robotics mentors mentioned a concern with developing tech talent. They see the difficulty their employers have finding talent and feel a need to help do something about that. The focus here is less about giving back to help individual students than helping to solve a larger problem for Milwaukee.

Pull factors

For the TEALS and FIRST Robotics mentors we interviewed, the programs satisfy mentors’ desire to give something back, and help develop tech talent. In these programs, however, mentors point to several other factors that drive their continued participation.

A chance to teach

“I’ve always wanted to teach at some point.”

“I’ve always had a passion for teaching.”

“I just love teaching, period.”

Both TEALS and First Robotics mentors mentioned the opportunity to teach as a key opportunity for them. While one of the mentors had started college as an education major, none of the mentors we spoke with graduated with education degrees. For those with a desire to teach, but lacking the certification to do so, participation in the programs as a mentor provides that opportunity.

A chance to inspire students/see them do cool things

“I want to help kids do cool, hard things.”

“I would like to see kids discover they have a passion for computer science.”

A number of the mentors we spoke with see in TEALS or FIRST Robotics a chance to inspire students in the same way they have been. They recognize that the ability to do so comes with a larger time commitment than other STEM outreach opportunities. One of the TEALS mentors mentioned the types of STEM outreach opportunities his employer offered, and what draws his interest:

> *... definitely the ones asking for volunteers that actually are less tour-guidey and more let's help the kids build something. We have the ones where you have to be the chaperone essentially, but personally I'd find myself more useful if help them [make something].*

The chance to inspire students and see them "do cool hard things" is, in large part, dependent on students' abilities to achieve success within the program. For mentors driven by this aspect of participation, the ability to see a path to student success is key. The FIRST Robotics competitions showcase this kind of achievement and allow potential mentors to see the kind of work students can do.

Several mentors mentioned, however, that the tight timelines of the FIRST Robotics season leaves little time for experimentation outside of design concepts the team is fairly comfortable will work. *"There is no time for, 'Well, that didn't work…' ".* They rely on pre and off-season activities with their teams to provide room for students to experiment, fail, and try again. Two of the mentors mentioned the longer timelines for VEX robotics competition allow greater opportunities for students to learn, to experiment, fail, and recover.

A second factor FIRST Robotics mentors consistently mentioned was the willingness of mentors from different teams to collaborate. Through the mentor network, teams will support each other with offers of parts or programming help, and, in the case of Riverside High School, access to the practice course the team set up within their space at the school.

The formal mentor network of FIRST Robotics is further supported through a weekly conference call during the build season for Rockwell employees who mentor teams. This provides another route to share knowledge between teams to the benefit of Rockwell mentors. Since they often support teams with parent mentors or mentors from other organizations, the knowledge shared on these weekly calls reaches an even wider audience.

TEALS mentors also called out a desire to see students succeed-- to go through a struggle that they are able to resolve. As one new recruit noted: *"I don't want my efforts to go into something that is going to fail."* For the mentors we spoke with, part of that success involves conveying broader lessons that are important to them:

> *For me, as long as I had a good syllabus and guide, I think the content is pliable. Meaning that I can inject my own experiences as to how this works in the real world... You build tool, you show it, you get feedback, you work to improve it-- it's an iterative process.*
>
> *I want kids to understand that not everybody that works in IT has a computer science degree. I want kids to see that the possibilities are there.*

> *They need to develop a thought process for working on problems. Everyone doesn't do it the same way. Everyone's head works differently. That's one thing I want to encourage-- they are unique, they are special, and their approach might be the best way. It's certainly the best for them.*

The mentors we spoke with have a fairly broad view of success. Winning regionals in First Robotics seemed less important than a good solution to one of the challenges faced in the competition. One mentor noted that the FIRST Robotics meets are a chance for students to see how someone else solved a problem they struggled with. When his students have struggled with a problem but are still excited to see a solution another team came up with, that's a win.

Mentors also count as a win students' ability to adjust to unfavorable circumstances. In the regional competition, Bay View's robot was not able to function as they had hoped in a role that could score points. The structure of the competition, however, puts their robot in an alliance with robots from two other teams. The Bay View team recognized that they could still successfully participate in a defensive role, blocking robots from the rival alliance from scoring.

Given a desire to see students succeed in their work, one of the mentors noted an aspect of the FIRST Robotics program he found particularly attractive-- the program was designed with a specific goal for students to achieve-- *"Build a robot that can do X. The robot can do it or it can't."* This makes it much easier for him to assess progress, and he contrasted this with mentorship opportunities where the role is to guide students in their thinking or development as a person where it is much harder to do so.

My company supports this work

Two of the mentors we interviewed were either self employed or retired. For those that were employed, the fact that their employer was supportive of their efforts is a factor driving both initial and ongoing engagement. Mentors from Rockwell and Northwestern Mutual reported first hearing about the FIRST Robotics and TEALS programs through their employers outreach efforts. Mentors working at Rockwell noted that they were not required to take vacation days to travel with the team and could use a corporate credit card for their travel expenses should the team move on after the regional competition. The other FIRST Robotics mentors we spoke with covered their own travel expenses.

Support from the mentor's manager was also important, particularly for TEALS mentors, whose time in the classroom occurs during the work day. Their manager's willingness to accommodate some flexibility in the mentor's schedule is necessary for participation. Depending upon the team's schedule, mentors in FIRST Robotics, at times, needed to leave work early to work with their teams during the build season. Here too their managers were willing to accommodate that work.

One of the Rockwell mentors noted that she has a performance goal tied to her First Robotics mentoring, which she takes as a strong sign of support. While other mentors saw opportunities for professional growth in their work with students, they did not report this sort of overt recognition from their employers.

A chance to expose students to things they won't get in school

"For a lot of these students, they are first generation college, or don't have exposure to engineering otherwise."

Several of the FIRST Robotics mentors view the program as a chance to provide exposure to engineering that isn't otherwise available to students. In some cases, the program was the only engineering option for students at the school. In other cases the team they work with is open to homeschoolers and students from other schools that do not have a team.

The Riverside High School team has access to equipment that PLTW classes in the school do not. They purchased their own CNC machine, so participation in the program provides students with their only chance to work with it. A mentor at another MPS school noted that for those students, participation in the FIRST Robotics competitions was one of the view chances they had to do something outside of the school.

A chance to build my own skills

"How many people get to graduate from college with experience managing a team of 30 and a $36,000 annual budget?"

"There's a really big learning aspect for me. There are so many different ways to approach a problem that sometimes we come in as engineers and say we must do xyz and kids will say let's do this. And it's like, yeah, I guess that makes sense, let's do it. There's a lot of value there ."

A couple of the mentors we spoke with could see where participation was a chance to develop their own skills. The FIRST Robotics mentor quoted above participated in the program while he was in high school and has been mentoring a team while he completes his engineering degree. Beyond the chance to give something back and help students find some of the joy he had in the program, he views his participation as a way to develop his own project management skills. One of the TEALS mentors found the classroom environment gave him opportunities to practice both retaining the attention of a room full of people and explain technical issues to individuals with less of a technical background. Both are skills he uses on a regular basis in his work.

Secondary factors

As we saw with teachers, not all of the benefits of participation are seen by mentors at the time they commit to lend a hand. The key factor for mentors in this regard was a chance to see students grow, and for several mentors, the transitions they found most compelling occurred over spans of a year or more.

See students grow

The compelling stories for mentors are those where they see students grow. One mentor, for example, told of a girl who came to the program as a freshman as a way to spend time with her boyfriend. That year she mostly sat in a corner and contributed little to the team. She started to get engaged in her second year and by that point had broken up with the boyfriend. By her third year she had formed an all girls team which she led.

A second mentor related a similar story. A freshman joined his team because his father, who is a teacher at the school made him. He came to nearly every meeting, but spent the time watching YouTube videos. The mentors were fine letting him do so. That year they won the local competition and had the chance to go to Detroit for the regionals. When the mentor asked this student if he would be going, the student asked, ‘Why should I, I’ve done less for this team than anyone else on it.” They convinced him to go anyway, and the experience of that competition “opened his eyes”. Now that student is one of the most dedicated team members and a leader within the group.

While an obvious source of pride for the mentors, the striking thing about these stories is the willingness of mentors to allow students to grow at their own pace. They are willing to let students remain loosely attached to the program for some length of time for these growth opportunities to occur. The mentors who told these stories also spoke of how student growth was more important to them than winning competitions. Both of those cited above worked with teams of mentors who had consciously worked to establish that culture. For one team, this led to occasions where mentors who did not share the perspective were asked to leave the program.

One of the TEALS mentors is at a school where this year, they have run semester long classes. He noted that teaching a group of students for a single semester, then starting in January with a new group, did not allow him to see as much growth in individual students as he would have wished.

On a much longer time horizon, one of the FIRST Robotics mentors has recruited students into Rockwell’s internship program for high school students. They have a couple who are now in

college, still working at Rockwell. Their success is an important benchmark for the mentor: *“I’m really proud of their accomplishments.”*

Inertia

Mentors’ desire to “give something back” through a program like TEALS or FIRST Robotics, and the time they are willing to devote to it, is weighed against two other factors-- the time they want to allocate to meet other personal or professional goals, and their ability to find other opportunities for giving back that may not require the same level of commitment.

Finding the time to do something more

Most of the mentors we spoke with noted that time spent mentoring was a balancing act with other priorities. Family, the desire to pursue professional goals, or an increased workload, might all intrude on mentors’ ability to continue working with students. FIRST Robotics mentors need to be confident that they can handle the 6 week crunch of the program. TEALS mentors want to feel confident they can meet the time commitment not just for the school year, but through the three year cycle TEALS plans for to get teachers up to speed.

There are lots of opportunities for giving back

Both TEALS and FIRST Robotics mentors mentioned that their employers provide multiple opportunities for them to get involved in STEM efforts. While not all of these opportunities will satisfy an individual’s desire to see students do cool things, or spark students interest in STEM, some potential mentors will find that worth trading off for a lesser time commitment or one that better fits their workload.

Anxiety

I don’t want to let down my colleagues at work

“I wasn’t concerned from a work perspective, it was more making sure everyone was on board [with my decision to participate]... I need to be cognizant of my time and how that impacts everything else.”

The mentors we interviewed noted that their employers and managers were supportive of their involvement. At the same time, however, they are concerned that the time they spend away from work during the workday not prevent them from keeping up with their workload. We did not hear this as a fear of being overwhelmed by their workload so much as not wanting to let their colleagues down. This appears to be more of a concern for the TEALS mentors, whose

volunteer time happens during the work day. This was less of a concern for FIRST Robotics mentors, where much of the volunteer work happens after school or in the evening.

Process issues reduce the likelihood that the team can succeed

Most of the FIRST Robotics mentors we spoke with had been involved with their teams for several years and had come up with workarounds to process issues that block students' progress. For a first year mentor we spoke with, however, process issues were top of mind and left some doubt about whether students could succeed in implementing their design-- not that they could not arrive at or build their design, but that process issues would eat away at the time they had to do so. For him, this list of issues included:

- Internet policies at the school blocked access to sites that would be useful to the team-- code repositories, etc.
- An inability for the mentor to connect his own laptop to the school's network
- Lack of cell service in the teams' work room which prevented him from setting up a mobile hotspot with access to the internet sites the team needed
- Loss of the teams' code from the prior year

The more time that both the mentor and team spent time on these issues, the less confidence the mentor had that the team could make could progress. Further, since these roadblocks are seen as low level issues, this left the mentor feeling like his time was being wasted-- he could have been working with kids on higher level problems but instead was simply trying to resolve connectivity issues.

Potential for burnout

"The kids are involved every day after school, Saturdays, Sundays..

FIRST Robotics mentors routinely mentioned the intense pace as the season kicks off, with students putting in long hours after school and on weekends as the competition date nears. While the time commitment is substantial for students, it places a similar burden on mentors. This is enough of an issue for some of the teams we spoke with that they have developed strategies to keep mentors from burning out.

Teams that have a large enough pool of mentors spread out the workload by rotating the days mentors are asked to work the kids. Another team we spoke with engages parent mentors with a timeline tied to their student's participation, ramping up participation as the parent gains comfort with the role, with a visible exit date when the student graduates or leaves the program.

Can I keep students engaged?

“The biggest fear is that [the students] wouldn’t be motivated.”

“I didn’t know what to expect from their kids. I didn’t know if they were going to bored. I was nervous about learning their names.”

The TEALS program has mentors take a leading role in the class as the teacher develops their knowledge of, and comfort with, the curriculum. While the mentors may, as noted above, have a desire to teach, they did express anxiety about their ability to keep students engaged, particularly if they ended up in a class where students were not already motivated.

Mentors also noted concerns about being able to structure tasks and provide support in ways that allow the students to remain engaged. Their ability to work with the teacher to adjust the curriculum and process to help do so has helped alleviate these concerns.

A related issue to mentors’ anxiety about whether or not students will be engaged is an expectation that teachers will handle classroom management-- e.g. if students aren’t engaged or there are behavior issues, the teacher will be there to deal with it. It should be noted that while teachers accept this role, they would rather have mentors who know how to work effectively with students.

Recommendations

Leverage Project GUTS

Project GUTS allows teachers to integrate exercises that build computational thinking into plans for material they already intend to cover. Teachers involved with the program recognize its value, can see opportunities where it can be used effectively, and are excited enough by the possibilities that they look to get colleagues involved.

There are a number of steps that could be taken beyond simply providing training to another cohort of teachers that could help speed adoption and effective use of the program. These are discussed below.

Support teachers who want to do more with Project GUTS

The teachers we spoke with all had specific ideas for the topics they'd like to explore with Project GUTS. Most looked at the summer as a time when they might be able to spend time to figure out how best to do so. Several also mentioned a desire to collaborate with colleagues at their own school or to connect with colleagues at other schools working on the same topics. Beyond having additional training or ad hoc support from district specialists, the current set of Project GUTS teachers could benefit from:

- A summer program to develop and test models and integrate into curriculum
- Establishment of network of local practitioners with regular opportunities to meet in person
- Provision of training opportunities to colleagues of current users

Create a framework to identify and leverage high value practices

The teachers we spoke with have already identified some initial ways to leverage Project GUTS curriculum to better serve their needs. What we did not hear was a framework that allows for rapid feedback and dissemination of these ideas to other MPS teachers working with Project GUTS. In TEALS a feedback loop is provided through the on-line tools noted above where teachers may suggest changes to the curriculum. While one teacher mentioned the value she would find in the chance to observe other teachers in action with Project GUTS, we did not hear of an opportunity for teachers observe each other or to give and receive timely feedback that would help them develop mastery with the tools.

The goal here is not to enforce "implementation with fidelity" around a standard way of using Project GUTS. Rather, we want to leverage the expertise and insights of those working with the program to enable teachers to more rapidly understand the most effective ways to use the tools

within their classrooms. This is an approach the Carnegie Foundation would call "Implementation with Integrity."[3] In recognition of both the autonomy they value and the expertise they bring, creation of such a framework should be driven by the teachers involved with Project GUTS.

Develop a mentor pool for Project GUTS teachers

While the teachers we spoke with were enthused about the possibilities of Project GUTS, they were also not completely confident in their ability to make full use of the tools without additional support. An outside mentor who can bring domain expertise around the systems to be modeled and some sense of how best to do so would provide welcome help.

The time commitment here need not be anywhere near as intensive as that required by TEALS. Having some availability to exchange ideas with a teacher and visit a class a few times per semester when students are working through models would be a valued addition to the support currently provided by colleagues and curriculum specialists within MPS.

Teachers value on-going relationships with mentors and want the same for their students. Having a mentor assigned to a teacher for the duration of a school year is preferable to a pool of volunteers where any one of whom might drop in on an ad-hoc basis. This partnership would be further enhanced if teachers have a chance to work with mentors who interests are strongly aligned with their own.

With the potential to use Project GUTS across multiple subject areas, the domains from which to draw industry expertise is fairly broad. In the search for mentors, this should allow tapping of existing networks of professionals who want to make a difference in Milwaukee, such as Milwaukee Science Advocates and NEWaukee. Mentors might also be drawn from members and supporters of advocacy organizations focused on issues that deal with the environmental, social justice, or other topics rooted in complex systems.

Showcase student work

Both the models students create within Project GUTS and they way these are used to help understand dynamic systems could provide great material to tell a compelling story for teachers looking to improve their practice as well as for potential mentors who want to see students "do cool things". Raising the visibility of this work could thus help recruit additional teachers and mentors to support the program. Two potential venues to do so are within MPS's annual STEM fair and STEM Forward's SySTEM Now conference.

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[3] https://www.carnegiefoundation.org/blog/what-we-need-in-education-is-more-integrity-and-less-fidelity-of-implementation/

Identify additional opportunities to integrate with curriculum

Teachers currently working with Project GUTS in concert with curriculum specialists should be able to identify areas within existing curriculum where use of the simulation tools is of particular value. These will be areas that look at complex systems where a few key parameters drive behavior of agents within the system.

While Project GUTS is largely focused on science, a broader look at where curriculum covers topics that involve dynamic systems will uncover additional areas where teachers find value in the tools. This exercise would allow MPS (or other school systems using the tools) to identify which classes might most benefit from the introduction of the Project GUTS. From that, one could identify teachers for subjects other than science who might be encouraged to make use of the program.

A look at opportunities to introduce Project GUTS across a broader range of subjects offers two key benefits. First, it increases the likelihood that multiple teachers at a school could make use of the Project GUTS tools. This would expand the pool of expertise with Project GUTS within a school and thereby offer more opportunities for teachers using the tools to find a colleague they might turn to for help. Second, a broader range of subjects where students get exposure to ProjectGUTS tools increases the likelihood that a student will be engaged with the tools in a subject area that interests them.

Target additional schools outside of MPS

The pilot effort within MPS has demonstrated the value of Project GUTS to teachers, but that value could be just as easily captured by other area schools. Further, a broad pool of local teachers who are adept in the use of Project GUTS tools and curriculum within their lessons would create additional opportunities to expose teachers to the tools and develop their skills in using them.

Consider cost of delay in providing support to teachers

Project GUTS teachers noted that their lack of coding experience has limited their comfort with the tools. The training provided was well regarded by the teachers we spoke with, it helped them see the possibilities of integrating the program into their lessons, and get to a point where they could do so. At the same time, the need to better understand the tools and how to effectively model dynamic systems was a common concern. This slows the pace at which Project GUTS is used effectively in the classrooms of teachers that have gone through training, as well as their ability to help their colleagues see value in and adopt the tools.

A delay in when teachers gain comfort with the Project GUTS tools delays when the value that comes from doing so is captured. While it may be difficult to quantify this value monetarily, it is a real thing. Were it not, there would be no point to implementing the program at all. In thinking through how and when to provide training and support to teachers to help them gain comfort with the Project GUTS curriculum and tools, the cost of delaying these efforts should be part of the equation.

As an example, getting a large group of teachers in the same room at the same time, reduces the training cost per teacher, but likely requires longer lead times to schedule. This, in turn, would reduce the likelihood that training will occur close in time to when it most useful to any given teacher. The net effect is to delay the point at which teachers and students start to see the benefits of that training. To wisely allocate resources, the costs associated with these delays need to be weighed against any potential cost savings that might come from training a larger group on a less frequent basis.

A related consideration is raised by the concerns of teachers about the amount of time they can devote to gaining comfort with Project GUTS and constraints on cognitive overhead among their colleagues. Introduction of the tools requires a small amount of extra effort on the part of teachers. If they are already overwhelmed by other initiatives or work in the classroom, adding a new task to master will simply delay the day they feel some sense of mastery with Project GUTS. With that, comes a delay in capturing the value such mastery brings.

MPS's opt-in model allows self selection for teachers with the capacity to take on the work. However, if we then ask them to take on additional tasks before they gain comfort with Project GUTS, that overhead could be lost entirely. In the product development world, this would be thought of in terms of queue size-- how many things can we have going on at once before the system is overloaded and the ability to move anything through to completion is compromised. In recruiting new teachers or assigning additional work to the teachers already involved in a program like Project GUTS, one should be mindful of the teacher's existing backlog and the delay that may be introduced in any of those efforts.

Encourage pair programming

Project GUTS offers curriculum focused on pair programming.[4] This offers students an experience that matches a practice used within a number of tech companies as a way to boost productivity of their programming teams. Used effectively, the practice allows pairs to provide on-going feedback on programming decisions, leading both to better designs and reduction of time spent on trivial bugs.

[4] https://teacherswithguts.org/resources/pair-programming-video

As teachers gain comfort with Project GUTS, incorporating the pair programming model provides a further opportunity for students to practice and develop collaboration and communication skills. It can also increase the likelihood of student success.

We assume that potential industry mentors to support Project GUTS would share the same concerns for student success noted by those we interviewed for TEALS and FIRST Robotics. An increased likelihood of student success from pair programming could help address these concerns.

Support, don't compel participation

The rollout of Project GUTS for MPS teachers as optional training allowed training to be directed at teachers willing and comfortable to take on a new challenge. We can imagine that if participation in training were compelled, MPS would have risked creating an environment where adoption of Project GUTS is much less likely to spread:

- Teachers would sense a loss of autonomy and would be more likely to enter training looking for reasons not to use the curriculum rather than looking for value in it.
- To ensure that training dollars were not "wasted" administration may have also been led to compel "implementation with fidelity". This would have reduced teachers ability to experiment with how and when to pull in Project GUTS and find those opportunities that work best for their students and themselves--e.g. where they find the most value.

Expand opportunities for block-based coding in elementary school

Block-based coding tools like code.org and Scratch provide interfaces that allow students to assemble code in an environment that allows for easy exploration while minimizing the opportunity for syntax errors. The greater comfort students have with these tools as they move to middle school, the easier time they and their teachers will have working with Project GUTS or other block coding tools that allow for more complex work.

Given what we've heard from teachers and mentors, we would look for opportunities that satisfy the criteria discussed below.

Students engage in coding as a way to explore or solve problems

As noted above, part of the attraction of Project GUTS is that it provides an opportunity to expose students to coding in ways that allow them to explore ideas and problems in science. The tools provide a way for students to test ideas and lets their curiosity around the topic or problem at hand drive their desire to master the coding required to do so. This approach offers both teachers and students many more possible points of engagement than would a program focused on simply learning how to code.

Program fits within curriculum

Project GUTS and DTC take two different routes to fitting within the curriculum-- as a tool to use within science lessons for Project GUTS, and as a program for an arts special with DTC. From a teacher's perspective, both solve the problem of "how will I teach this class" in ways that offer advantages over what they might otherwise do. Were these programs instead offered as independent curriculum that teachers were asked to make room for we'd expect much less enthusiasm for the programs.

Teachers have effective support

Teachers want to feel supported in their work. Effective support provided as part of a program or through a pool of mentors who can work with teachers to understand how to use and leverage coding tools to support the work at hand can:

- reduce the anxiety of teachers who do not have a coding background;
- help teachers see a path to mastery of the tools;
- allow teachers to find new opportunities to leverage the tools;

Attracting a pool of mentors will be easier to do if mentors can see that the teacher is engaged and enthusiastic about the program and the teacher has the support from building administration and other community partners that will allow students in the program to succeed.

Provide room for students to experiment, fail, and recover

Both teachers and mentors noted the value in having students take risks and learn from their mistakes. Both also noted that students need room to do so. Here, room to experiment, fail, and recover means not just time, but an environment where they are comfortable with failure. Software development is an iterative process. Students need the chance to practice learning from things that didn't go as they might have expected.

By giving students room to experiment, fail, and recover, we increase the likelihood not just that they will succeed in their work, but that they might do so in unexpected ways. This can be a key motivator for both teachers and mentors that can help keep them engaged in the work.

Employer support for mentors

Demonstrate that employer values mentors' work with students

Mentors want to know that the time they spend with students is valued by their employer and that it does not distract from the work their team needs to complete. While mentors recognized that work with K-12 students can provide an opportunity to develop skills they can leverage in the workplace, few of those we spoke with indicated this was recognized by their employer.

We noted above several ways in which mentors' employers signal their support this type of work:

- Regular announcements of opportunities for community engagement
- Active recruiting efforts for participation in mentorship activities
- Scheduling flexibility to accommodate the volunteer efforts of mentors

Overt signals from the employer that mentorship work is valued as a professional development opportunity by the firm will leave mentors more willing to participate. As examples, a firm might:

- Provide employer sponsored opportunities for mentors to learn how to effectively engage with students-- this would demonstrate an employer's commitment to the effort and also help mentors be more effective in the classroom
- Incorporate meaningful student mentorship as a recognized track in building leadership and communication skills for employees
- Provide opportunities for mentors' students/teachers to share their work with co-workers. This could come through on-site presentations, newsletter articles, or by encouraging attendance at off-site presentations.

Facilitate deep connections between mentors and the classroom

The desire for teachers to have support they can count on, and for mentors to have a chance to see growth are more easily satisfied when mentors have an ongoing role with the class or classes they support. Mentors who have built good relationships with the students they work with are an asset to the teacher and allow the teacher to play a higher value role within the classroom.

As one of our DTC teachers put it:

> *I you really want this program to succeed, give us people… [N]ot just volunteering once in a while. Assign one or two of your engineers to work with a specific classroom. Have them work all year with them. Have them teach me how to better teach [design thinking] and I want to learn from watching them work with students… That's what I want.*

Provide adequate materials

We noted above how the expectation that teachers provide materials for STEM exercises pushes some away from doing the exercises at all. One of the DTC teachers offered a broader view on the importance of having an adequate supply of materials: *“I want [enough] materials so my students [won’t] be afraid of trying, taking bigger risks.”*

The physical activities within Project GUTS and DAT’s prototyping exercise demonstrate the potential for approaching problems in ways that develop skills useful in computational thinking without actually working on a computer. They offer a high level of student engagement and the chance to experience a concept or problem in a different way. However, if physical activities are to be included within a program a teacher is asked to implement, the cost of those materials should not be the responsibility of the teacher.

References

Project GUTS

Website: https://teacherswithguts.org/
StarLogo Nova: https://www.slnova.org
Walk & Turn Exercise: https://teacherswithguts.org/resources/walk-turn-starlogo-tng
Flower Turtles Project: https://youtu.be/rEXSntQr_uU

SHARP Literacy

Design Through Code - http://sharpliteracy.org/codewithart/

TEALS

Website: https://www.tealsk12.org/

FIRST Robotics

Website: https://www.firstinspires.org/robotics/frc

VEX Robotics: https://www.vexrobotics.com/

Other Block-based Coding Tools/Curriculum

Scratch: https://scratch.mit.edu/
Snap!: https://snap.berkeley.edu/
Beetle Blocks (3D design): http://beetleblocks.com/
Beauty and Joy of Computing: https://bjc.edc.org/
Blockly: https://opensource.google.com/projects/blockly