MICRO:BIT AND THE GROWING NEED FOR EDUCATION OF COMPUTER SCIENCES IN DETROIT PUBLIC SCHOOLS

Prepared for: The Detroit Public School District Board

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Executive Summary

On July 13, 2020, our team had received approval on our research on the BBC micro:bit to improve computer science and technological education in the Detroit Public Schools Community District (DPSCD). In doing so, our goals were to study national issues in Computer Science Education, determine technologies that will be dominant in society, examine the BBC micro:bit microcontroller device for its use to teach programming and microcontroller technology in secondary schools (specifically in the DPSCD), devise criteria for assessing BBC micro:bit, and present our findings, including a recommendation. In our study, we addressed these problems:

- Only 40 percent of American schools teach computer programming or coding, even though computing jobs are the number one source of new wages in the United States.
- Our country has nearly 9 million available jobs in STEM with some 70 percent in computers and engineering. with more than a half-million of those computing jobs currently unfilled and projected to grow at twice the rate of all other U.S. jobs. Only 49,300 computer science graduates joined the American workforce last year.
- There is a gap of interest between genders in IT and engineering, thus reducing, even more, the potential workforce; only a few high school students choose to take stem fields as electives, such as electronics, information technology, and computer programming.
- When introduced to coding at an earlier age, students do not seem to have any interest in the subject, therefore not having the ease of transitioning with the technology as they progress through their grades.

We researched the BBC micro:bit and compiled information through primary and secondary research on computer science education, as well, and learned the following information:

- Teachers are willing to learn new technology if given their district's support and help in implementing training in classrooms.
- Teachers, administrators, and board members think CS can be integrated into common core curriculum.
- An overwhelming majority of parents, teachers and administrators believe the CS education is as or more important than common core subjects.
- The United Kingdom's schools had great results with the device just after one year of its introduction.
- The price point of the micro:bit is vastly lower than competing educational robotic kits, being approximately 25% of the cost of Arduino and Lego Mindstorms™.
- The micro:bit offers a variety of popular programming and web tools at a lower cost than competitors with less installations and peripherals required.
- The micro:bit's application allows you to change things in the JavaScript side, and appears on the block side correctly in block form and vice versa, helping both students and teachers learn a second language faster.

On the basis of our analysis, we recommend that Detroit Public Schools, through corporate funding, have one micro:bit for every freshman to start and 15 –20 additional kits of sensors and components for advanced projects for every science and technology classroom. The combined retail of these is around $45. These devices best meet our technical and cost criteria.

Introduction

As a way to improve computer science and technological education in public and secondary schools, we have studied the problems in computer science education, microcontrollers and the technology such as the BBC micro:bit that may be worth integrating into schools that will inspire more students to pursue STEM careers, as well as how it could impact education as a whole.

Currently, the future of the job market in the U.S. is growing toward technology. Public schools and post-secondary schools are falling behind by following teaching curricula that is irrelevant now. The Computer Science Teachers Association (CSTA) points to the decentralization of the public-school system and standardized testing as the biggest problems. Most public schools follow national teaching guidelines—the Common Core—and complete standardized tests based on those, with states and local bodies making the classroom-level decisions. Schools are not keeping pace in filling the need for tech workers even though computing jobs are the number one source of new wages in the United States. Over a half-million available computing jobs in the U.S. are currently unfilled and are projected to grow at twice the rate of all other U.S. jobs. The potential workforce is reduced more due to the gap of interest between genders in IT and engineering and the few high school students choosing to take stem fields as electives. When introduced to coding at an earlier age, students also do not seem to have any interest in the subject, reducing the ease of transitioning with the technology as they progress through grade levels.

Therefore, we looked to determine the best way to we could improve this situation for the Detroit Public Schools Community District (DPSCD). To do so, we performed the following tasks:

- Gather secondary research on the state of current computer science curriculum and the reasons for the shortcomings in U.S. secondary schools.
- Conduct primary research by interviewing computer science educators in the Detroit Metropolitan Area.
- Conduct secondary Research of the BBC Micro:Bit.
- Conduct primary Research of the BBC Micro:Bit by experimentattin with the device.
- Assess the results been in the UK since BBC Micro:Bit's Debut in 2016.

We found that STEM teachers included in our search unanimously agreed that CS should include both end user applications and computer programming. Most teachers also agreed that the common core has hampered CS education in their districts and that they would integrate CS into common core curriculum, if given the resources, and that how computer science and tech subjects engaged more students compared with other classes they have taught.

Our principle findings regarding the micro:bit are that the micro:bit has a low barrier to entry, allows users to be creative and have fun, provides educational value to students and teachers of various levels of expertise, embeds that nature of future devices, and is applicable beyond computer science. Giving the micro:bit to schools, opened computer science as an option for more students, while lessening the interest gap between men and women in computer science as a career choice and giving confidence to teachers in teaching computer science.

In the following sections, we provide details about our research, results, conclusions drawn from the results, and our recommendation.

Part I: A Look at Computer Science Education

Independent Research Study of Computer Science Education

We conducted a survey of Science, Technical, Engineering & Mathematics (STEM) teachers, mostly in the Detroit Metropolitan Area, to get their opinions of the current state of Computer Science (CS) curriculum in their districts. Unfortunately, the committed respondents to this survey from the Detroit Public Schools Community District (DPSCD), the focus district of this study, did not return their questionnaire. The remaining teachers who did participate still gave us an adequate representation and diversity we desired when reaching out with requests. Our respondents were 50% male, 50% female. One teaches in standard public high school. One teaches at a public high school that focuses on the arts and technology. One teaches in a middle school. One teaches in a special education high school. Two currently teach computer science solely, while the other two teach mathematics and engineering classes and 3 mentor and coach after school coding and robotics clubs. The exact racial makeup of the group is unknown.

CS is not a nationally standardized curriculum as are other STEM subjects like math and science. Computer science can mean anything from learning end-user applications like MS excel (Kohli, 2015) to computer programming. We asked our participants if CS should include both end-user applications and computer programming and they unanimously agreed yes. When asked if they had control over a resource pool, what percentage of resources would they devote to each, their answers average out to 62% for computer programming 38% for end-user applications like MS office, etc. Leslie M., a math teacher that teaches students on the autism spectrum and at-risk students had this to say:

> *"There needs to be a mixture of both. In my experience, many students, especially students who are deemed at risk, might have the necessary basic skills to operate their smartphone but might not be able to navigate a computer. Many schools are heavily relying on Google Suites for word processing, spreadsheets, slides, etc. Wealthier districts that use iPads rely on Apple's Pages, Numbers and Keynote. Microsoft Office is really being edged out of the education sphere and there seems to be less and less incentive to teach students a particular platform and more incentive on helping kids figure out how to use a platform intuitively. Teaching programming is a continuation of teaching kids how to intuitively engage with technology to solve problems. Instead of being taught separately, they should ideally be taught together."*

Jim M. who teaches engineering courses at an area high school also added this:

> *"Since programming is more of a development tool, more resources should be focused on it especially in these times of the competitive evolution of AI, 5G and autonomous transportation technologies. Most end-users possess enough problem-solving capability to access tutorials or can figure out how to use the other software on their own."*

We wanted our research to explore teachers' attitude toward advanced training on top of what they are already credentialed in. We asked if the district offered free micro-credentials in a particular programming language or new technology, how willing would you be to volunteer for this training:

Very Likely	Somewhat Likely	Neutral	Not Likely
25%	75%	0%	0%

Figure 1: Teachers willing to volunteer for CS training

Our respondent Leslie M. added this:

> *"...it would depend on whether I would be offered time to complete the course and whether the district would support the implementation. (Many times, districts send us to trainings but then don't have the resources to allow us to use what we learned)"*

Most public schools follow national teaching guidelines, the Common Core and complete standardized tests based on those, but US states and local bodies make classroom-level decisions, according to a report published by the Computer Science Teachers Association (CSTA) (Kohli, 2015). We asked if common core has hampered CS education in their district these were the results:

Definitely Yes	Somewhat Yes	Very Little	Not at All
25%	50%	25%	0%

Figure 2: Has Common Core hampered CS education?

Jim M. had the strongest opinion on this saying, "Common core in my opinion is the most ridiculous and destructive force in American education." Continuing with common core and standardize testing, high schools are becoming more focused on college prep, and underperforming schools keep falling behind. There is evidence that underperforming schools are excelling in after school activities such as robotics competitions (Matte, 2020). When asked their thoughts about coding & computer science being taught in secondary schools focused as a "career" prep curriculum, like typing and shop class once were, Leslie M, and Joe Minnick gave us some thought provoking answers:

> *"In the United States, the general push has been to do away with vocational/technology programs because the perception and most often the reality was that BIPOC [Black, Indigenous and People of Color] students were funneled into those programs. As programming becomes more of a necessary skill, it would probably be more palatable."- Leslie M.*

> *"Every day I hear of huge shortages in skilled trades. We are experiencing tremendous successes with students who attend career related programs and after school clubs. Many students are attending colleges with no focus on specific careers and colleges frankly are not delivering any real-world content. Many students I know are not being successful at American universities. Over the past few years, I have experienced an influx of skilled trade workers asking to recruit from my classroom. A common message is they*

cannot find people to fill the vacancies in many trades including computer programmers. Many students are being recruited into boot camp programs for computer programming, which are effective but extremely costly. I think computer programming needs to be carefully considered as part of the required curriculum since there still seems to be a lack of interest and awareness resulting in small class sizes making it vulnerable to the 'chopping block.'"- Jim M.

Our respondents all agreed that if a computer programming class were mandatory, and the district had the resources and faculty to teach the classes, that the students would have more interest than in a traditional math or science class. They also enthusiastically agreed that computer science could be integrated within common core curriculum. For instance, teaching a math segment with Python math tools like you would traditionally on a graphing calculator.

Continuing our look to gauge student's attitudes towards CS curriculum we asked our respondents how computer science and tech subjects engaged students compared with other classes they have taught:

More	Same	Less	Depends on Student
75%	0%	0%	25%

Figure 3: Current student engagement in CS curriculums

Finally, we asked are participants to tell us where CS education needs improvement:

"Funding is not sufficient; student interest is low and there is too much emphasis on college prep"-Jim M.

"There is a huge gulf between the haves and haves nots. CS should be equitable across all districts and schools."-Leslie M.

"Cybersecurity and artificial intelligence."-Josh Pudaloff

"First and foremost, I think boards of education need to understand that by 2020, computer science and tech ed should be mandatory and a requirement at every level. In my district, you do not need to pass your computer classes to move to the next grade; computer education is not offered at every grade. Students are much more knowledgeable than their teachers about how to use various social media and music types of software & hardware; yet lack basic skills on communication & presentation software and ethics about virtual responsibility."-Joi Thrash

Gallup & Google's Study on Computer Science Education in 2016

In 2016 Gallup and Google released a comprehensive, two-year research study to better understand perceptions of CS and access to CS learning opportunities in K-12 schools in the U.S. More than 16,000 7^{th} through 12th-grade students, parents of 7^{th} through 12th-grade students and K-12 teachers, principals and superintendents were surveyed (Gallup, 2016, p. 3). Here are a few of the reports key findings.

Their survey stated that both parents and educators, as was ours, were enthusiastic about CS education in their schools. The survey Gallup (2016) conducted found:

> The vast majority of parents (84%) and majorities of teachers (71%), principals (66%) and superintendents (65%) say that offering CS is more important than or just as important as required courses like math, science, history and English. A majority of educators feel that students should be required to take CS in schools when it is available (60% of teachers, 62% of principals and 56% of superintendents say this) (p.3).

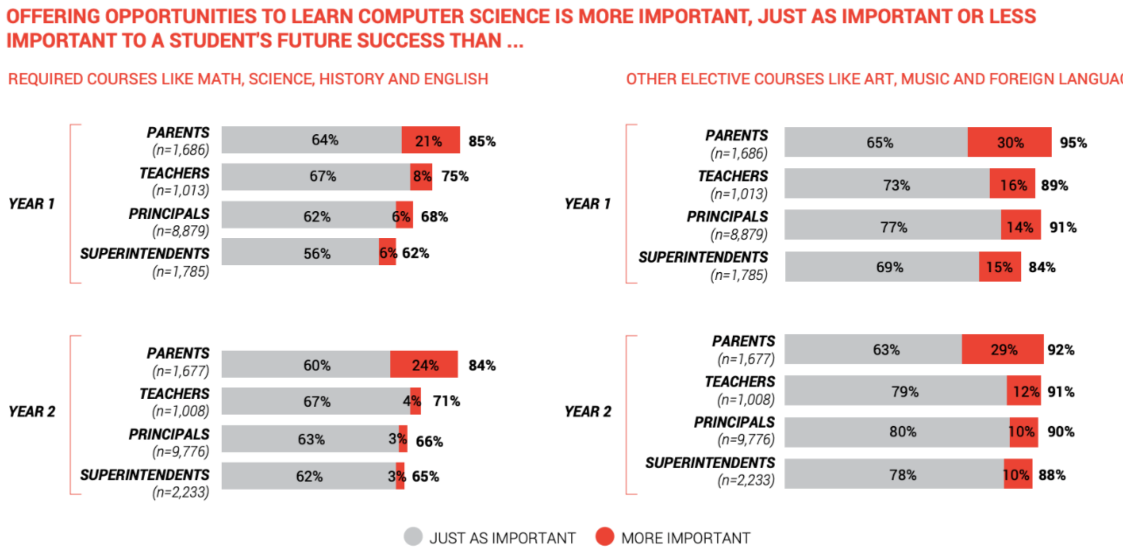


Figure 4 : Importance of CS classes in K-12 survey *Source:* Gallup Inc. & Google Inc. (2016)

One reason, their survey suggests, for the lack of CS curriculum in schools is a failure to be vocal about it, despite the strong support. The Gallup (2016) report concludes:

> Although the majority of parents value CS, few have approached school officials to specifically express support for CS in the classroom, and educators do not report that CS is a priority at their school/district, which may be hampering CS offerings. About three in 10 parents (28%) or teachers (30%) have specifically expressed support for CS education to school officials. While a majority of principals (56%) and superintendents (62%) have expressed at least some support for CS to their superiors, just one-third or fewer agree that CS is a top priority in their school or district. Principals at larger schools, private schools and high schools are more likely to agree that their school board is committed to offering CS and that their guidance counselors think it is important to offer it (p. 4).

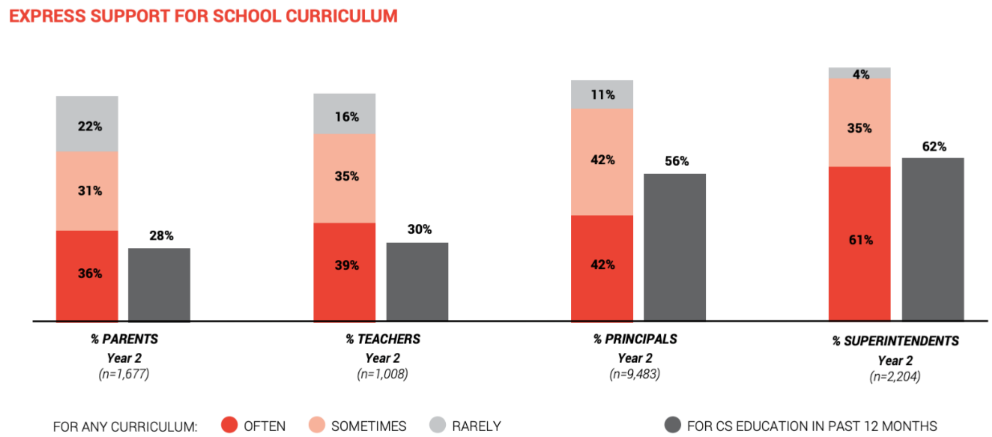


Figure 5: Expressions of support for CS curriculums
Source: Gallup Inc. & Google Inc. (2016)

Finally, the Gallup survey touched on the problem that some of our respondents also found as a problem for the lack of CS education in public schools. The lack of resources and the schedule time that needs to be devoted to classes for standardized test subjects or common core curriculum. The survey also mentions a problem with a lack of trained teachers to teach computer science courses. I think this is where the DPSCD is at, and a problem we can address in our study. Gallup (2016) found that:

> Schools report a lack of qualified teachers and funds as key barriers to offering CS. Additionally, schools continue to report that they have too many other classes that support required testing for students, which may immobilize some schools from adding CS offerings, especially in lower grade levels.
>
> - Sixty-three percent of K-12 principals and 74% of superintendents who do not have CS in their school or district say a reason they do not offer CS is the lack of teachers available at their school with the necessary skills to teach it. Additionally, at least half of principals and superintendents (50% and 55%, respectively) note that they must devote most of their time to other courses that are related to testing requirements.
> - High school principals without CS classes are more likely to cite a lack of qualified teachers (22%) and lack of student demand (19%) as the main reason for not offering CS than they are to cite too many classes related to testing requirements (14%) (p. 4).

Part I Conclusions

Matt Siegelman, CEO of career analytics firm Burning Glass, was quoted in an interview for Quartz.com where he stated, “A national non-STEM job opening is filled in about 33 days, compared to 56 days for jobs that require programming skills and 65 days for mobile developing," he goes on to say "There'd be more people to fill these jobs if there were more computer science graduates, and there'd be more graduates if more people could start the subject in high school. And yet it's difficult to find a high-quality computer science class in American high schools, let alone a programming class (Kohli, 2015)."

Computer science education in U.S. public high schools is not a can that we can kick down the road to college anymore. Not all the high skilled jobs will require a college degree, but most of the high skilled jobs will require programming experience. A four-year degree has more than doubled in average cost over the past 30 years and is often an enormous financial burden. Student loan debt now totals more than $1.5 trillion and Americans with college degrees are three times more likely to be employed than U.S. high school graduates (Dearborn, 2018). And as our respondent Jim M. stated, many of his tech students do not succeed at four-year colleges.

There are many positives to take from both studies. That teachers are willing to learn new technology if they have the district's support in helping them implement the training in their classrooms. There is a majority of parents, teachers, and administrators that highly value CS education and that they want to see it integrated in the other standardized subjects as this graphic in figure 6 shows.

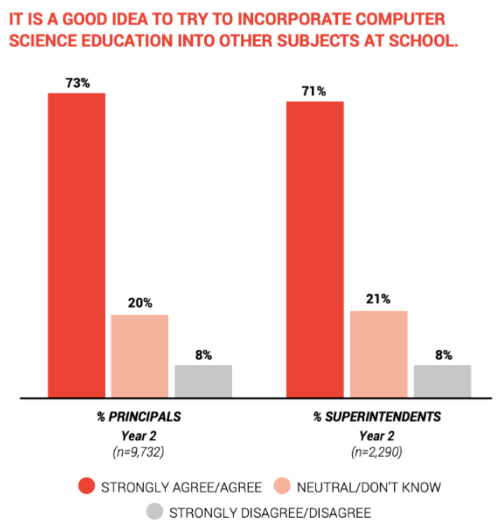


Figure 6: Support for integration of CS into other subjects

Source: Gallup Inc. & Google Inc. (2016)

Teachers believe that students will be more engaged with CS education and School boards are also more enthusiastic than expected about computer science curriculum. Could the only problem be that the supporters of more CS education are not being as vocal about it?

That may be one of the issues, but there are still some hurdles. Common core is not going away anytime soon, so a solution must be found to work within common core. The solution must also address the lack of funding and qualified teachers. There is indeed a disparity between wealthy and poor districts and there should be a way to achieve equity. And after that, how can we make the students learn it.

Another disadvantaged school district, Chicago Public Schools has made CS part of its city-wide core curriculum, the same can be done with the DPSCD. The research we have done should address all the hurdles mentioned above. With the success DSPCD already has had with corporate donations from Quicken Loans to donate robotic kits for elementary schools (Clifford, 2018) and FANUC's two Detroit high school robotic training programs (Chambers, 2018); additional funding from a city full of high tech companies who need high skilled workers should not be too difficult if the solution is correct. We believe our research has found this solution.

Part II: The BBC micro:bit

In 2015, the BBC launched the Make It Digital initiative. Concurrently, there was a nation-wide mandate to teach computer science at all grade levels in U.K. schools (Austin, et al., 2020). The BBC micro:bit is a small programmable and embeddable computer designed and developed by the BBC and several other corporate and nonprofit partners. It was given free of charge to approximately 800,000 year 7 students in the U.K. in 2016 with the hope of developing a new generation of tech pioneers (Austin, et al., 2020).

Research from the Association of Computing Machinery (ACM)

The BBC spent two years researching already established technologies to get more students involved in computer programming and improving digital literacy. According to a report by Jonny Austin, et al. (2020), research shows that physical computing—combining software and hardware to build interactive physical systems that sense and respond to the real world—can engage a diverse range of students. The simultaneous global interest in the maker movement also suggests an appealing way to engage children is to incorporate making, creating, and inventing as part of the software development process.

The BBC and its partners had to develop its own device, the micro:bit, as an inexpensive, powerful, and easy-to-use learning tool guided by five major design goals as stated in Austin's, et al. (2020) report:

1. *Have a low barrier to entry.* Financial cost and simplicity are important considerations for any technology, but even more so in an educational setting. The micro:bit needed to be affordable, easy to deploy, intuitive to use, simple to program, and integrate well with existing school IT infrastructure.
2. *Be fun and creative.* The micro:bit itself needed to offer an exciting, engaging, inclusive introduction to coding and making. Inspired by Arduino and the maker movement, the project sought to turn teachers and students from digital consumers into digital creators by integrating the micro:bit into their own real-world, physical creations.
3. *Have a low floor, high ceiling, and wide walls.* When designing the micro:bit, providing good educational value to students and teachers was the prime consideration. It needed to be easy for inexperienced learners to get started (low floor); enable rich learning opportunities that grow with user expertise, provide progression in both programming language and application complexity (high ceiling); and enable students to reach the ceiling via multiple pathways to embrace a diverse audience (wide walls).
4. *Open a window into the future.* Computing technology is becoming ever more ubiquitous, connected, and embedded. In the 1980s, the BBC Micro captured the essence of the devices that were to come over the next 30 years: the desktop PC. The micro:bit was designed as a modern-day equivalent, capturing the connected, embedded nature of devices that are to come for the next 30 years.
5. *Be applicable beyond computer science.* Cross-curricular activities can offer diverse and inclusive learning. This is important when we consider the gender disparity in computing today. The micro:bit project aimed to stimulate curiosity about how computing can be

applied across a variety of disciplines, ranging from science and technology/engineering to the arts and mathematics (STEAM) (Austin, et al. 2020).

(a)
front, with two buttons,
5x5 LED display,
and edge connector (bottom)

(b)
back, with processor, accelerometer,
compass, Bluetooth,
USB and battery connectors

Figure 7. The BBC micro:bit. *source: Communications of the ACM*

The U.S. based international society for computing, the Association of Computing Machinery (ACM), the world's largest scientific and educational computing society (Karoff, 2019) published a report in their journal *Communications of the ACM* in March of 2020 a study of the micro:bit after four years of its introduction in the U.K. The report's nine authors are comprised of academics, researchers at Microsoft Research in the U.S. and the U.K., and researchers at the Micro:bit Educational Foundation. The report by the ACM (Austin, et al., 2020) reflected on the design goals stated earlier:

- The micro:bit's inexpensive hardware lowers the financial barrier to entry for students, parents and teachers. Its Web-based software requires no installation, lowering technical barriers to adoption in schools and homes. The micro:bit's integrated sensors and outputs allow students to explore a range of lessons and projects without the need for external electronic components.
- The design of the device prompts a sense of fun, alongside colorful programming blocks that allow for complete control over the device and its peripherals, backed up by a range of creative learning materials and projects.
- Programming experiences spanning Blockly, JavaScript and Python provides a clear progression path when combined with project-based learning. Radio and Bluetooth networking allow further progression to more complex projects with other micro:bits, smartphones and other Internet connected devices.
- Finally, the ability to run on battery power combined with sensors, non-volatile storage and edge connector allows for the integration of the micro:bit into areas of the curriculum that make use of physical experiments and data collection(Austin, et al., 2020).

Discovery Research Ltd Survey of the micro:bit one year after initiation

Independent research was undertaken in the U.K. by Discovery Research. Unfortunately, for our study we were not able to get Discovery Reseach's entire report, but were able to get key results from a bbc.co.uk media centre article on the survey. An independent survey (qtd. in BBC, 2017) of 405 U.K. school children and their teachers concluded that:

- "90% agree that BBC micro:bit helped to show them that anyone can code.
- 88% agree that BBC micro:bit helped them to see that coding isn't as difficult as they thought it was.
- 45% said they would definitely do Computer Science as a subject option in the future, up from 36% before they used BBC micro:bit.
- 70% more girls said they would choose computing as a school subject after using the micro:bit."

And, amongst teachers:

- "75% of teachers have or are intending to use the BBC micro:bit by the end of the summer term.
- 85% agree that it has made Computer Science more enjoyable for their students.
- 80% agree that it helped students to see that coding wasn't as difficult as they thought it would be.
- Half of teachers who've used the BBC micro:bit say that they now feel more confident as a teacher, particularly those who say they're not very confident in teaching Computing."

A teacher from Manchester, U.K., an industrial city with underperforming schools similar to Detroit, MI was quoted in the article, saying that:

> *"Micro:bits have given an exciting edge to the classroom enabling all pupils to bring their creativity to computing. I have seen, through my work as a CAS master teacher and in my own school, the micro:bit inspires pupils to learn to code so they can make things happen. The micro:bit has changed the shape of my teaching curriculum; they have become an integral part of the curriculum giving hands on projects to link physical computing with the abstract programming concepts in some of the national curriculum. We have launched rockets, built robots and created music all with the micro:bit* (BBC, 2017)*."*

Experimenting with the micro:bit

One of our group members conducted primary research on the micro:bit to get a firsthand look at this device. He purchased the micro:bit for $18.50 and a box of sensors and other components for more advanced experiments for $28.15, far less than the average cost that U.S. school districts pay for textbooks (Zook, 2017).

He did many experiments with the micro:bit, but for the sake of brevity we will only show you highlights from his first experiment and some of his methodologies. This was an experiment that started simple that he could build upon to get familiar with the micro:bit, the expansion peripherals, and the online software. He also wanted to test the micro:bit for its durability. Without having a school year to see how it would hold up to wear and tear of students, A research assistant, Richard "Rusty" Sabaugh, age 2 of Brooklyn, NY was employed to expose the machine to a rigorous battery of environmental hazards, such as milk, juice, unwashed hands, and general careless use. Then handing back over to our researcher to continue his experiments. We assumed this will provide a proper analog of the duty cycle of the micro:bit in a single school year. **See figure 8.**

Figure 8. Research assistant testing micro:bit at lab bench.

He started with a project to show his school pride. He used the micro:bit to make a "heart shape" using its built-in 5X5 red LED matrix, then he hooked it up to an expansion board so he could then connect a larger 16X8 green LED matrix to display the letters "WSU." **See Figure 9.**

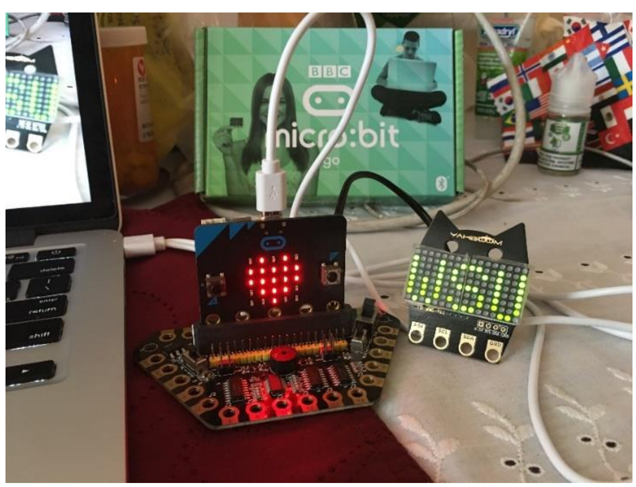
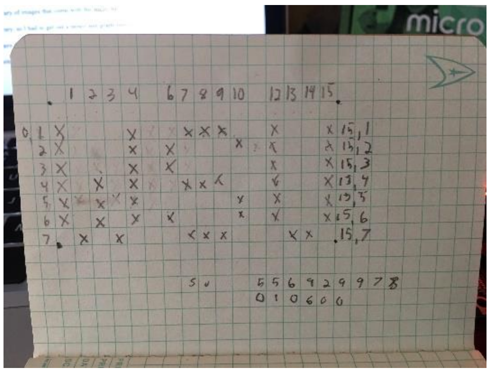


Figure 9. I Love WSU Project.

The heart shape was easy as there is a built-in library of images that come with the micro:bit. The expansion 16X8 matrix had only a small library, so he had to use a pencil and graph paper and plot his own WSU block letter logo. **See figure 10**. Then, enter each plot point into the block-based editor. **See figure 11**.



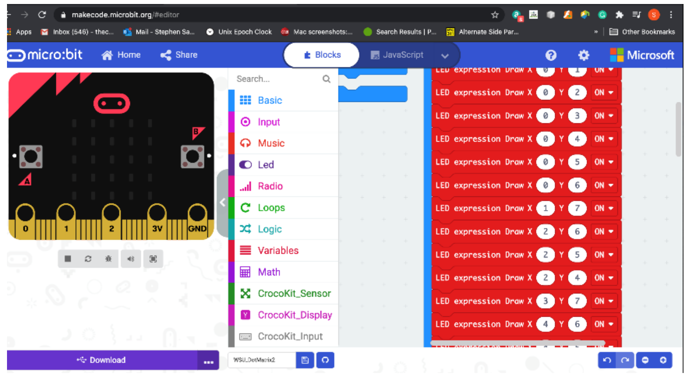


Figure 10: WSU logo paper plot **Figure 11: WSU logo in blocked-based editor**

Then he wanted to write a function, so he would have a piece of pre-written code that he can use in his programs with just one line of code, a function call, saving him from entering each of those 46 plot points each time he wanted to use his WSU block text logo. He did not know how to do that in a block-based editor, but he did know how to write a function in JavaScript. So, clicking on the JavaScript side of the editor he wrote the function and it was done. An instantly, the block-based version appeared on the block-based side. **See figure 12**.

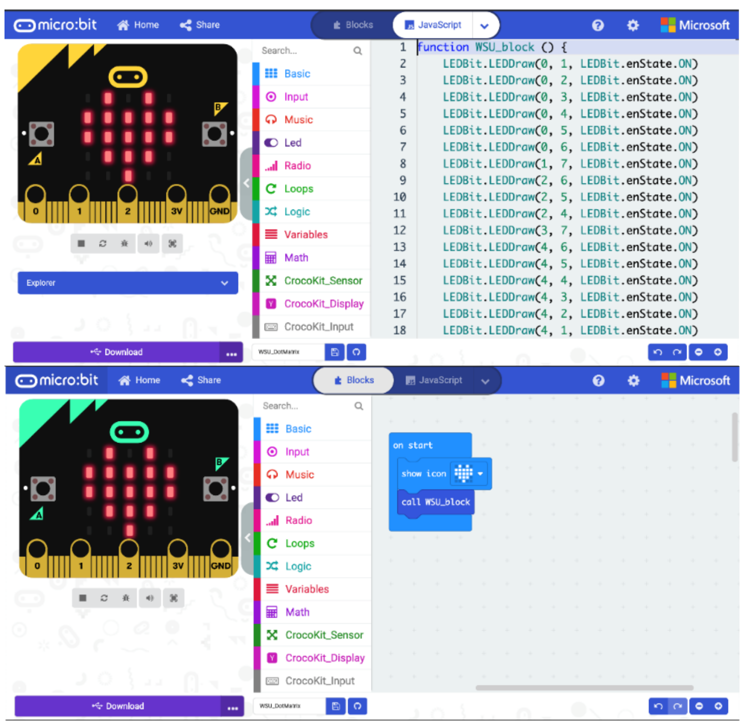


Figure 12: JavaScript code for WSU heart

There are a few switches and several pins that may seem daunting when you first look at these expansion boards. Our team member was not sure what most of them were for, but it is by no means a hindrance to learning. When you need to know something, the instructions are quite clear. As for the ruggedness experiment that research assistant Rusty Sabaugh conducted, the micro:bit and the peripherals held up well to the toddler's "Underwriters Laboratories-esque" abuse on the machine. An alcohol wipe effectively cleaned up the juice and food particles.

Part II Conclusions

Based on the five design goals that the BBC had for the micro:bit, here are some reflections. Our researcher owns several similar Arduino devices and peripherals as well as educational robotics kits like Lego Mindstorms™, and the price point is vastly lower with the micro:bit. The difference in price for similar experiments is approximately 25% of the cost of Arduino and Lego Mindstorms™. Unlike the Arduino, the micro:bit can do many experiments with no peripherals at all that can teach students many concepts about programming. He found the web-based software to be as impressive as the micro:bit itself. There is nothing to install. The website offers MS Makecode, a block-based programming language designed for kids; JavaScript, one of the most popular front-end web application languages; and Python, a powerful language used in many applications. The Makecode editor has a clever feature, a dual block-based/JavaScript editor. The drawback to block-based coding is looking for all the blocks in a list. Or, if you are an experienced programmer who knows how to easily do something in a traditionally typed programming language, it can be difficult trying to figure out how to teach the "simple" block-based programming to kids. The micro:bit's application allows you to change things in the JavaScript side, and it appears on the block side correctly in block form and vice versa. This helps not only students, but teachers learn a second language faster. Eliminating the frustration of installation of device drivers and special programming software will make the integration into an educational setting much easier. All that is required is a device with a web browser. A physical micro:bit is not even necessary to code and test your programs, as the online web-app includes a micro:bit emulator.

There is no doubt that this device is fun. If our researcher did not set a time limit for himself trying new experiments, he would still be tinkering with the device. Now as for high school students, it certainly must be more fun than programming basic exercises on a computer. Any serious programming class requires the instruction of basic concepts. Because of a student's limitations, there are not really any real-world applications you can teach those basic concepts with. The micro:bit comes stock with an accelerometer, compass, Bluetooth, radio, 2 buttons and a 5 X 5 LED matrix screen than can scroll letters across and display simple images and animations. These are experiments that you cannot do in a programming 101 class even at the college level. So, if this device does not make coding fun for students, it is difficult to see what would. Although our researcher has experience programming and using similar devices, he was learning a brand-new system, one that he found to be completely different. He experienced joy learning it and seeing just what else he could do with this little device. With the frustration free ease of the software, the virtual foolproof connections of peripherals, and the countless amounts of projects and lesson plans for teachers, including a classroom management system, any credentialed teacher in any subject, could be effective CS educators with this device. The one thing that the micro:bit nor the Micro:bit Educational Foundation provided was the six-essential soft skills that good teachers possess according to an article from Cappella University (Cappella University, 2018); leadership, communication, teamwork, problem solving, social and emotional intelligence, and cultural competence. These, along with the tools that are offered by the Micro:bit Educational Foundation should allow for an easy transition with existing school infrastructure for teachers and allow for integration of the micro:bit into a teachers' current curriculum.

A few days with the micro:bit have easily demonstrated the *low floor, high ceiling, and wide walls* design approach. Our researcher's previous experience with programming and wiring almost hampered him at first. As soon as he began to just follow lesson tutorials, he really was impressed at what an incredibly effective device this can be to learn computer programming. In his academic career, he has taken at least five college-level, introduction to programming courses in five different languages. The concepts are taught in such a fun and clear way, and the results are so gratifying that you could easily cover a semester's worth of college material in a high school class and have higher retention rates, because the results are things that everyday items like smartphones and wearables do. The *high ceiling* is only limited by the device and your own imagination. That may sound cliché, but that is what happened to our researcher. He simply ran out of time and ideas to test the device farther. The fact that students can use languages used in professional development such as JavaScript and Python means they will not outgrow the device, or at least the lessons learned from it. The only limit reached on this device is with the 15kb of internal program memory when attempting some complex experiments. The *wide wall* idea is that students can basically find just about any project for this device that suits their interests. Our researcher could not even get through reading half of the list of projects on the microbit.org site. There are numerous mathematical functions included in the programming software, making it as suitable for math subjects as a graphing calculator. The micro:bit allows for the applied study of mathematics, while still being able to teach the basic concepts behind the application. Besides traditional STEM subjects, there are plenty of Art and Music applications for this device, even Physical Education is covered, with step counters and stopwatches and that is just what I found on their website. Our researcher is already thinking about how he would make a heartbeat monitor.

ACM's professional insight of the micro:bit's four-year life span and Discovery Research survey's finding are so encouraging; it is hard to determine that these results have not made an impact on decisions of U.S. public schools to consider the micro:bit for a computer science curriculum. Also, with the math and science tools that are included, this device and accompanying software, could have tremendous success in standard curriculums like math and science. Considering that a great effort is being made to lessen the gender gap in tech in this country and we are facing a tech job shortage as well as wealth inequality, why would we not try using a system that has proven success in other public schools. Our research presented here through both primary and secondary sources leads us to conclude that this a game changing technology in education.

Our Recommendation

In the first part of the of our report we distilled the problems of CS education down to 5 problems

- Lack of funding and resources and disparities between rich and poor districts
- Lack of qualified teachers for CS education
- Common core and standardized testing
- Student interest
- Supporters of CS education not expressing their opinions effectively

We believe that the micro:bit solves all of these problems if implemented well.

The micro:bit is very inexpensive and only requires a basic computing device with internet access. We think that through corporate funding, that DPSCD should follow the U.K.'s lead and have one micro:bit for every freshman to start and 15 –20 additional kits of sensors and components for advanced projects for every science and technology classroom. The combined retail of these is around $45. This is significantly less than the $190 retail that Quicken donated (Clifford, 2018) for robotics kits. The price would also plummet when bought in bulk.

The micro:bit requires only a very brief training seminar to have teachers using it in their classrooms. In fact, there is a very easy yet comprehensive tutorial right on the micro:bit.org website. There is also a classroom management feature to assist teachers running multiple micro:bit experiments in their lessons.

The micro:bit sytem can easily be integrated within in a math or science curriculum. The python programming language, which is used with the micro:bit is stocked with very advanced math tools that can cover any mathematic subject. The fact you can also teach applied mathematics with this device is just an added benefit. Alone the software is more capable of solving any problem using a graphing calculator. Teaching a student to solve a problem on both a scientific/graphing calculator for standardized testing and using Python and the micro:bit will only give a student more preparation for college and the real world.

The studies from the U.K. support the claim that students really like the micro:bit and have change their perceptions of computer science. It also has impacted young woman the most. Piquing their interest in a way that no other girl's coding initiative has.

Finally, someone from our research team would be glad to do formal demonstrations of the product and the curriculum for your board, teachers, students, parents or whoever you think would like to know more about this technology and also get firsthand experience so that support can be gained district wide.

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Appendix A

Prepared by: Blake Smith

Arduino UNO REV3 (Arduino UNO REV3)

- Microcontroller: ATmega328P
- Operating voltage: 5V
- Input Voltage (Recommended): 7-12V
- Input Voltage (Limit): 6-20V
- Digital I/O Pins: 14
- PWM Digital I/O Pins: 6
- Analog Input Pins: 6
- DC Current per I/O Pins: 20mA
- DC Current for 3.3V Pin: 50mA
- Flash memory: 32KB
- SRAM: 2KB
- EEPROM: 1KB
- Clock Speed: 16MHz
- LED_BUILTIN: 13
- Length: 68.6mm
- Width: 53.4mm
- Weight: 25g

Raspberry Pi 4 Specifications (Raspberry Pi 4)

- Broadcom BCM2711, Quad core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz
- 2GB, 4GB or 8GB LPDDR4-3200 SDRAM (depending on model)
- 2.4 GHz and 5.0 GHz IEEE 802.11ac wireless, Bluetooth 5.0, BLE
- Gigabit Ethernet
- 2 USB 3.0 ports; 2 USB 2.0 ports.
- Raspberry Pi standard 40 pin GPIO header (fully backwards compatible with previous boards)
- 2 × micro-HDMI ports (up to 4kp60 supported)
- 2-lane MIPI DSI display port
- 2-lane MIPI CSI camera port
- 4-pole stereo audio and composite video port
- H.265 (4kp60 decode), H264 (1080p60 decode, 1080p30 encode)
- OpenGL ES 3.0 graphics
- Micro-SD card slot for loading operating system and data storage

- 5V DC via USB-C connector (minimum 3A*)
- 5V DC via GPIO header (minimum 3A*)
- Power over Ethernet (PoE) enabled (requires separate PoE HAT)
- Operating temperature: 0 – 50 degrees C ambient

Microcontrollers vs microprocessors (CircuitDigest.com, 2015)

- Key difference in both of them is presence of external peripheral, where microcontrollers have RAM, ROM, EEPROM embedded in it while we have to use external circuits in case of microprocessors. This means that microcontrollers are smaller and more compact, and also better at saving power, but microprocessors are generally best for more complex jobs because of the capacity for much larger externals, such as RAM.
- As all the peripheral of microcontroller are on single chip it is compact while microprocessors are bulky
- Microcontrollers are made by using complementary metal oxide semiconductor technology, so they are far cheaper than microprocessors. In addition, the applications made with microcontrollers are cheaper because they need lesser external components, while the overall cost of systems made with microprocessors is high because of the high number of external components required for such systems.
- Clock speed of microcontrollers are generally 8-50MHz, while clocks speeds of microprocessors is usually above 1GHz.
- Microcontrollers store program memory and data memory on separate drives, while in microprocessors those are stored together.

ARM chip (Raspberry Pi (Trading) Ltd., 2020)

- BCM2711 contains the following peripherals which may safely be accessed by the ARM:
  - Timers
  - Interrupt controller GPIO
  - USB
  - PCM/I2S
  - DMA controller
  - I2C masters
  - SPI masters
  - PWM
  - UARTs
- Max operating frequency of the general-purpose clocks is 124MHz
- ARM Quad-A7 core datasheet may also be helpful

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Appendix B: The Application of Computer Technology in the Construction Industry

Prepared by: Matthew Robben

When discussing the growing need for education in computer sciences and programming, for the work force of tomorrow, we examined one industry that the implementation of new, automatized technologies is already beginning to transform. The construction industry has for the most part used the same materials and processes to complete projects for centuries but the decline of young people entering the workforce while budgets and schedules tighten, has amplified the demand to increase productivity in new ways. This has in turn led to the boom of innovative technologies such as drones, sensors, and robots. However, in order to successfully integrate these technologies into the industry, new positions have started to be created for people with the skills to not only operate them but innovate them in ways to better facilitate the industry's needs.

Drones and Reconstruct

Ryan Moret, Field Solutions Manager, McCarthy Building Companies said in the 2018 article, *The Rise of Drones in Construction:*

"*Drones change the game in communication. A [drone] photo is worth a thousand words, and potentially millions of dollars*."

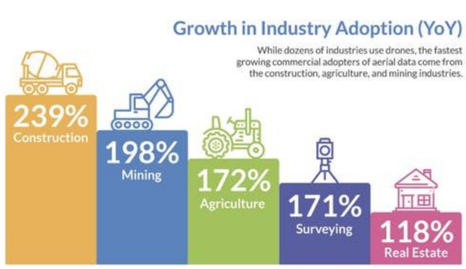

Figure 13: Drone use growth by Industry *Source:* Drone Deploy (2018)

According to a study conducted by Drone Deploy in 2018, no industry had shown more growth in the use of drones than construction. See **Figure 13**. By attaching a camera to a drone, operators are able to take high quality progress photos from aerial views without having to be on site. However, innovative engineering has now taken the technology even further. A new software called Reconstruct is in its final stages of development and beginning to be functionally tested on a small number of construction sites today. One of these projects just so happens to be where I am currently working as a technical coordinator. I have been able to witness firsthand the amazing capabilities of this new software. Essentially, Reconstruct is a software in which camera footage taken from a 360 degree camera mounted on a drone, can be uploaded as a layer, directly over a BIM model so users can actually navigate a 3D model of the site from anywhere in the world. See Figure 14 below.

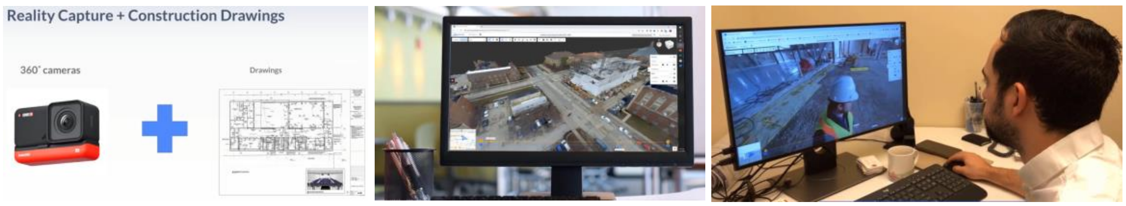

Figure 14: Reviewing Reconstruct Footage

Soucre: Reconstruct Inc. (2020)

With the data collected in a single shoot, this software can analyze and determine areas of high risk for workers, closely estimate material quantities to validate costs, and even generate accurate status reports to indicate whether the progress is on schedule or not. It goes without saying that this software is going to change the industry as we know it. With Reconstruct, construction managers will be able to collect a wealth of data with less personnel on site and share progress, safety, and engineering reports in the clearest and most accurate way possible thus far.

Sensors

Sensor technology is also changing the industry as innovation continues to progress and open up new and amazing opportunities to not only increase productivity but actually potentially save lives. One such innovation has been the introduction of wearable proximity sensors that can ensure employees working in during the current COVID pandemic a maintaining recommended social distancing while on site. Companies like *Actility*, are producing *Smart Badge* sensors like these that can also track interactions between people identified as infected with the Coronavirus and those who they came in contact with, to identify a contamination cluster and stop the spread. See **Figure 15**.

Figure 15: Actility Smart Badge Sensor

Source: Actility Smart Badge

Robots and Modular Construction

Finally, the last of the rising technological trends covered in this research is the one which will produce the most change in the industry in the near future, Robots. While usually thought to be paired with the manufacturing industry, automatized robots are beginning to be used more and more in construction. While much interior work is still to integrate and confined for automatized construction, the rise of modular building has become the gate way in which robots can replace the need for human labor. Ryan E. Smith , University of Utah Chair, Off-Site Construction Council, National Institute of Building Sciences defines modular construction in his 2016 article *Off-Site And Modular Construction Explained* as

> "*Off-site construction involves the process of planning, designing, fabricating, transporting and assembling building elements for rapid site assembly to a greater degree of finish than in traditional piecemeal on-site construction*."

This ability to build off site, gives opportunities for companies to manufacture small sections of buildings in assembly line style with robots that can build faster for cheaper than their human counterpart. Quality of these buildings can be tracked directly from the manufacturer in an isolated location to insure sections are built per design.

Appendix B Conclusion

In conclusion, we reviewed many new and exciting technologies being implemented in the construction industry today that will have resounding impacts on the future workforce. While at first glance these innovations can look like they will replace the need for human workers, they are actually opening up more opportunities for workers who have skills and knowledge in computer sciences and programming. If you are looking for a reason to increase the education of computer sciences and programming for the workforce of tomorrow, look no further than construction as one of the many and growing industries in which this knowledge will soon be essential.

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