An interdisciplinary collaboration between computer engineering and mathematics/bilingual education to develop a curriculum for underrepresented middle school students

Sylvia Celedón-Pattichis • Carlos A. LópezLeiva • Marios S. Pattichis • Daniel Llamocca

Abstract There is a strong need in the United States to increase the number of students from underrepresented groups who pursue careers in Science, Technology, Engineering, and Mathematics (STEM). Drawing from sociocultural theory, we present approaches to establishing collaborations between computer engineering and mathematics/bilingual education faculty to address this need. We describe our work through the Advancing Out-of-School Learning in Mathematics and Engineering (A-OLME) project by illustrating how an integrated curriculum that is based on mathematics with applications in image and video processing can be designed and how it can be implemented with middle school students from underrepresented groups.

Key words: Interdisciplinary Collaboration • Mathematics Education • Image and Video Processing • Underrepresented Students • STEM

Introduction

Nationwide, percentages on 8th-grade mathematics performance show that only 7.8 % of students achieve the excellence level; in New Mexico, at the 46th place nationwide, only 3.7% of students do so (Education Week 2012). Additionally, culturally and linguistically diverse students are still underrepresented in the Science, Technology, Engineering, and Mathematics (STEM) fields (Syed and Chemers 2011). The Advancing Out-of-School Learning in Mathematics and Engineering (A-OLME) project—with a relevant, high-level standards integrated curriculum—aims to establish a pipeline of support and motivation for predominantly Latina/o middle school students to engage in and eventually pursue an engineering and/or mathematics career. Therefore, the main goal of this project simultaneously aligns with a strong, current national priority of increasing access into STEM fields for students from underrepresented groups (NRC 2011).

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The STEM Education Coalition also argues that in order to develop a scientifically literate citizenry and inspire students to pursue STEM fields, education should promote greater and more evident integration between mathematics and engineering concepts (Shaughnessy 2012). Nonetheless, the process of teaching and learning in engineering has mostly been done by people who have been trained in the engineering field and not by people with specific training and research in the area of education (Johri and Olds 2011). Thus, this project comprises an innovative approach as it combines the expertise, knowledge, and experiences of professionals from both engineering and mathematics/bilingual education fields.

Moreover, it has been argued that the majority of middle school students “were uncertain or not interested in engineering due to a lack of knowledge, inferior perception of science skills, or interest in a different career” (Mooney and Laubach 2002, p. 317). Thus, our goal is to promote explicit and engaging activities for middle school students where they can solidify and improve their mathematics knowledge; uncover the field of engineering through digital image, and video processing; and hopefully realize that they, as Latinas/os, already have engaged in engineering practices and may learn, do, become, and belong to (Wenger 1998) the engineering community.

In the next few sections, we first describe the composition of the team. Then, we discuss how sociocultural theory informs this interdisciplinary collaboration (John-Steiner 2000), including the approaches used to design a curriculum that was suitable for middle school students from underrepresented groups. In addition, we describe the contributions of the two fields by illustrating a sample task that integrated the ideas of all team members. We end with a discussion and implications of our interdisciplinary collaboration.

Composition of the team

The ideas for A-OLME began with informal discussions between Profs. M. S. Pattichis and S. Celedón-Pattichis, who often discussed approaches to jointly design a curriculum that would connect mathematical ideas with engineering concepts. However, it was not until Prof. C. A. LópezLeiva joined the faculty in the same department as Prof. S. Celedón-Pattichis that an opportunity to fund a postdoctoral fellow to help design and implement the curriculum presented itself. Prof. C. A. LopézLeiva had heard Profs. M. S. Pattichis and S. Celedón-Pattichis discuss some ideas of A-OLME, and he encouraged both to apply for the funds from the Office of the Provost to help secure a postdoctoral fellow from electrical and computer engineering to help with the project. Prof. M. S. Pattichis is a faculty member in the Department of Electrical and Computer Engineering, and Profs. S. Celedón-Pattichis and C. A. LópezLeiva are faculty in the Department of Language, Literacy, and Sociocultural Studies with areas of expertise in bilingual and mathematics education. In addition, Prof. C. A. LópezLeiva had also worked with afterschool programs and designing out-of-school learning. The postdoctoral fellow we selected, Dr. Daniel Llamocca, has expertise in computer engineering. In the process of implementing the curriculum, our goal was also to work with undergraduate students as facilitators so that we reached an equal number of team members from engineering and from education. After forming the team, we realized that there were some basic principles that can help guide a successful collaboration across disciplines. We address these guiding principles in the next section.

Theoretical and practical underpinnings of our collaboration

We draw from sociocultural theory (Vygotsky 1978) to frame not only our interdisciplinary collaboration but also our work with middle school students from underrepresented groups, who included mainly Latina/o students from low to middle socioeconomic backgrounds. In the A-OLME project, we realized the importance of complementarity in our collaborative efforts (John-Steiner 2000) among computer engineers and mathematics/ bilingual educators. Each collaborator—including the postdoctoral fellow, the professors, and the facilitators—was viewed as an important contributor of knowledge in his or her area. Together, we approached our work from a sociocultural understanding of collaboration and co-construction of knowledge among those engaged in a shared initiative. Each brought unique strengths to the project to reach a common goal (John-Steiner 2000). In order to achieve a common goal, we argue that a fundamental pre-requisite for the success of interdisciplinary teams comes from the need for *mutual respect*. We use the term *mutual respect* to refer to the value that each places on each other's ideas that goes well beyond an invitation to be an external reviewer on a project, for example, and positioning one another as experts in the respective fields. There has to be a fundamental respect to each other's fields of study and what each field has to contribute to the research in order to move a common goal forward. Mutual respect for each other's disciplines was based on (a) the appreciation of the engineering members that the mathematics and language educators will help them build engineering problem solving using mathematical tasks, and (b) the appreciation of the mathematics and language educators that the engineering collaborators will help them understand issues associated with access of underrepresented students to STEM fields.

Building on mutual respect, there is the expectation that the interdisciplinary effort will lead to significant contributions to each other's disciplines. There needs to be a balance between these contributions. There should not be significant contributions towards one discipline while there are minimal contributions towards another discipline. Overall, as the collaboration continues, an integration of ideas between disciplines will emerge and the boundaries between disciplines begin to disappear (John-Steiner, 2000). The integration of ideas will require non-traditional thinking that will force the collaborators to step outside their traditional discipline boundaries. It is important to be willing so as to be able to bridge the gap between the disciplines.

The collaborators will need to be patient, investing their time in understanding each other's language and perspectives. In our view, language is a mediating tool (Vygotsky, 1978) that serves to understand each collaborator's views and understandings of working with underrepresented groups of students. "Collaboration thrives on diversity of perspectives and on constructive dialogues between individuals while creating their shared voice and vision" (John-Steiner 2000, p. 6). An example of the difficulties in integrating mathematics education with computer engineering came from the differing perspectives of students' experiences and backgrounds. The engineering collaborators did not appreciate issues associated with low socio-economic status (SES) and issues of access to technology. For the engineering team members, working with underrepresented groups of students simply meant recruiting females, Hispanic, and African American children without the need to distinguish between the schools where they were coming from. By attending several school events such as afterschool tutoring and graduation, the mathematics/bilingual education team members attempted to recruit students from low SES schools that did not necessarily have a focus on technology. Yet, initial response showed that these attempts would not produce sufficient numbers of low SES students. The engineering members of the team believed that this recruitment problem would also persist to a lesser degree with middle schools emphasizing mathematics and science curricula that make extensive use of technology. They urged the mathematics/bilingual team members to recruit from these schools. Yet, reluctantly, at the persistence of the mathematics and language educators that no recruiting was needed, no team members participated in any recruitment. Instead, the team sent an email to the school administration of a mathematics and science charter middle school announcing the summer school program. The school administration forwarded the summer school announcement to the parents with the following text:

> "Attached is the flyer for all XXXX middle school students."

To the great surprise of the engineering team members and not to the mathematics/ bilingual education team members, there was a strong response to this single-line email. What was shocking to the engineering team members was that there was no endorsement for the students to participate in the program. Furthermore, the email was sent on the last day of classes. Thus, there was no hope to do any recruitment even if we wanted to. We had 50 students reply from this single email. Only eight were accepted into the program from that particular school.

To understand further issues associated with low SES that the engineering team did not originally appreciate, we focus on issues of access. Prof. M. Pattichis believed that middle school students were primarily *consumers of technology* and that there was a need to support them as *producers of technology*. He believed that the students would already be playing with mobile phones and computers and would thus have some basic knowledge of computer literacy. The mathematics/bilingual education team members did not make the assumption that all children would have the same access to this technology. In practice, we found strong variations in the students' background. Computer and mobile phone access was an issue for the children from low SES backgrounds. Some of the children were very unfamiliar with using the keyboard. And nearly all of the children complained about *excessive typing* and the difficulty associated with the need to *memorize commands*.

Another topic where there was a big difference in the team's expectations on what the team should be doing came from how to build the curriculum. In engineering, the basic approach is to have lectures followed by lab exercises. However, it is hard to engage the students during the lectures. The mathematics/bilingual education team members promoted the importance of *interactive learning* where the students learned what they needed to do by engaging in carefully designed tasks, observing the results, and extending the concepts in follow-up problems. In engineering, the primary purpose of many of the exercises is *problem solving*, and there is often little focus on critical thinking and collaborative learning. Yet, for mathematics education, the focus is on *inquiry-based learning and communication*. Thus, in education the focus is on solving problems as well as posing questions that guide students to explore different concepts.

Despite significant differences in technical language, we found a common ground through the identification of concepts that are used similarly within the two groups. For instance, in Computer Engineering, *functions* are thought as short sequence of commands to perform a task. Mathematical *functions* can only be defined through equations. Here, the engineering use of functions was found to include and extend the traditional use of mathematical functions. Thus, while we introduced both, the term was reserved for the engineering interpretation. On the other hand, computer array indexing was related to coordinate systems.

Also, bridging the gap between the disciplines came from the re-interpretation of traditional mathematical *functions* as *images* and *videos.* A two-dimensional discrete-valued function became an image composed of picture elements. We discuss these connections in the task described in Figure 2. In the next section, we describe how the team approached the design of the curriculum.

The curriculum

The curriculum tasks include a careful selection of mathematics—proportional reasoning, geometry, and algebra—and engineering including manipulation of digital image and video through open-source computer platform concepts. We developed a set of tutorials and activities for middle school students and for undergraduate facilitators from education and engineering fields. See Table 1 below for a list of topics developed as part of the curriculum. We expect, as the current research (Douglas, Christensen, and Orsak 2008) on the topic suggests, that by teaching image and video processing students can grasp fundamental mathematics and engineering concepts.

Table 1: Summary of Topics for Mathematics and Engineering Summer School 2012

WEEK	SESSION	SYNOPSIS	ACTIVITIES
1	1	Basics of MATLAB	▪ Basic mathematical operators. ▪ Basics of MATLAB scripting. ▪ Introduction of the concept of variable ▪ Common calculator functions: addition, subtraction, multiplication, division. ▪ Other calculator functions: square, square root.
	2	Representation of black and white images in MATLAB/Octave	▪ Create a black & white picture and ask a partner to follow your directions. ▪ Create rectangular shapes in MATLAB ▪ Create black & white pictures in MATLAB ▪ Extract portions of a figure in MATLAB
	3	Operations with black and white images.	▪ Rotations, reflections, translations ▪ Students apply these operations to the images they took
	4	Area estimation in black and white images	▪ Students calculate the area of an object (white areas/black areas) inside an image.
2	5	Logical operations with black & white images	▪ Logical operators AND, OR, XOR, and NOT are introduced ▪ Students apply logical operators on black &

			white images. ▪ Students solve imaging problems by using logical operators.
	6	Create a video with a series of black & white images	▪ Students create a sequence of binary images ▪ Students learn how to create a simple video and play it.
	7	Representation of grayscale images	▪ Students create their own 5 x 5 grayscale images. ▪ Use tiles of different grayscales to create an activity ▪ Students read a grayscale image file and display it on the screen.
	8	Concept of Histogram	▪ Students are given a pencil-and-paper activity to understand the concept of histogram ▪ Students compute the histogram of a grayscale image in MATLAB.
3	9	Grayscale to binary conversion	▪ Students learn the use of converting a grayscale image to its binary counterpart. ▪ Students learn the fundamentals of thresholding ▪ Students learn the process of grayscale to binary conversion.
	10	Color images	▪ Students learn about color image acquisition. ▪ Students learn to manipulate color—Red, Green, and Blue—RGB—images. ▪ Students convert a RGB image to its grayscale counterpart.
	11	Project	▪ Students are given clues and aides to their projects.
	12	Project	▪ Students are given clues and aides to their projects.

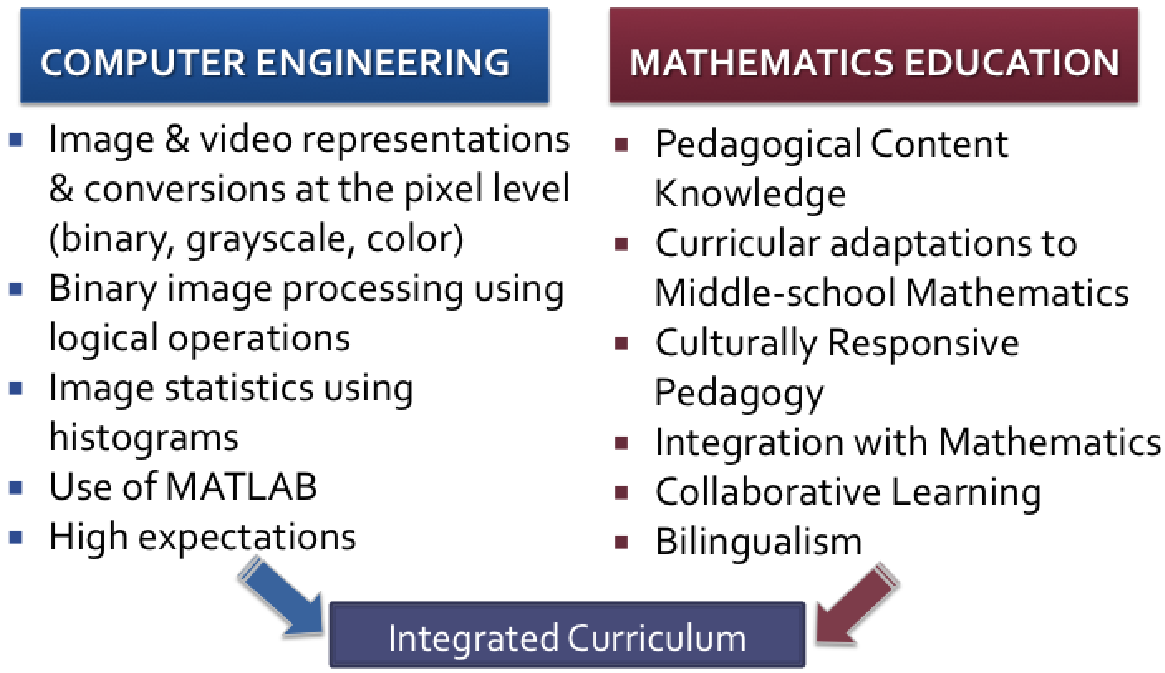
Theoretical foundation of the curriculum

The integrated curriculum is founded on principles of reform-based mathematics instruction for middle school students (Celedón-Pattichis 2010) and attempts to make connections between the Common Core State Standards for Mathematics—or CCSS-M (National Governors Association Center for Best Practices 2010) and the Computer Engineering Standards (2004). Our tasks attempt to promote mathematical practices supported by the CCSS-M: 1) make sense of problems and persevere in solving them, 2) reason abstractly and quantitatively, 3) construct viable arguments and critique the reasoning of others, 4) model with mathematics, 5) use appropriate tools strategically, 6) attend to precision, 7) look for and make use of structure, and 8) look for and express regularity in repeated reasoning. In order to implement these practices in the engineering context, students generate and manipulate digital images and video having laboratory experiences using Octave/Matlab. These experiences promote the manipulation of these data, and concepts include a backwards design (Wiggins and McTighe 2005), as students move back and forth between real data to completely digitized information. Thus, activities include pencil-and-paper, modeling, and computer-based tasks. Rather than planning for the accomplishment of measurable objectives, we center on how to respond to a set of key questions related to students' deep and enduring levels of understanding about the concepts and experiences supported by A-OLME.

These activities require the students to process digital images and videos. These means provide a real-world problem context for students to mathematize or participate in model eliciting activities, which are considered productive ways to integrate mathematics and science (Hamilton, Lesh, Lester, and Brilleslyper 2008). Later on students enter and transfer their findings into computing platforms that help them confirm, diagram, manipulate, and learn from the information. An extensive literature review on teaching image and video processing to high-school students supports that digital image and video processing provide a rich learning resource to teach engineering and science concepts (Karam and Rice 2000).

Our approach is founded on a participatory, situated, and experiential engineering learning perspective (Johri and Olds 2011), where the development of engineering and mathematical identities is parallel to the process of learning (Litzinger et al. 2011). We expect this identification to be manifested through both students' own narratives and their appropriation of scientific—mathematical/ engineering—discourse practices (Chval and Khisty 2009). Therefore, in the process of implementing and evaluating the efficiency of the program, we focus on the quality of engagement that curricular activities support; how they relate to students' current knowledge, interests, and experiences; and how they further support their meaning-making process of the targeted concepts (Warren and Rosebery 2008), especially of underrepresented students, as they learn in out-of-school settings (Willey, LópezLeiva, Torres, and Khisty in press). As a result, we monitor and analyze the curricular implementation by exploring students' joint action in small groups, participation in the curricular activities, and how they acquire and/or transform practices that they use to reason and understand mathematics (Radford and Roth 2011) and engineering concepts. In the next section, we describe the contributions that the computer engineering and mathematics/bilingual education team members made to develop an integrated curriculum.

Fig. 1: Integration of computer engineering and mathematics education content into an integrated curriculum



Integrated design

From the computer engineering perspective, the goal was to provide understanding down to the basic picture element, the pixel. We wanted to focus on information that individual pixels carry without worrying about their relationships to other neighboring pixels. Middle school students were familiar with the concept of color. At each pixel, color was introduced to them as a collection of three numbers representing the red, green, and blue components. For gray-scale images, instead of having three numbers per pixel, we have a single number that represents the shade of gray that we are working with. Then, the simplest image is made up of black-and-white—0 or 1—values for each pixel. We use the term *binary images* to refer to the black-and-white images.

To understand the composition of images and videos in terms of pixels, there was a need to view images as a collection of little squares arranged in *a coordinate system*. Similarly, to work with binary images, we need to cover mathematical content associated with *logical operations*: "or," "and," "not," and "exclusive-or," "xor." As an example, "xor" is used to take differences between binary images. Logical operators are not covered in middle school mathematics. Thus, the coverage of logical operations provided an example of having to step outside traditional boundaries. Since logical operators are very fundamental to computing, we believe that the introduction of logical operations in middle school mathematics provides basic support to students in pursuing careers in computing.

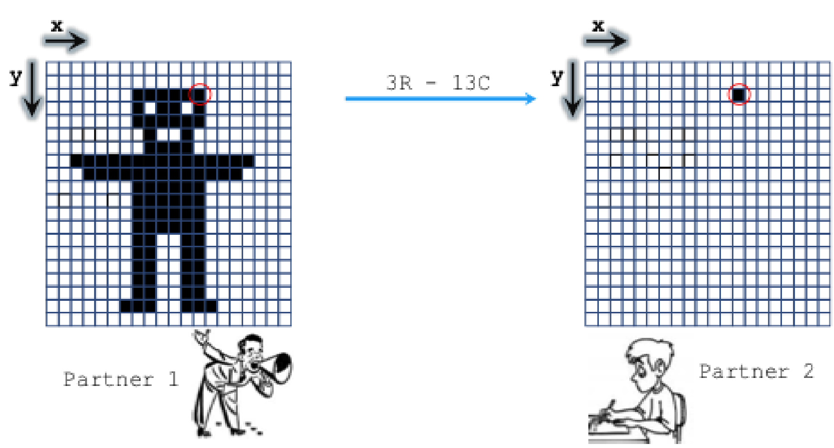
To process gray-scale images, there was a need to build a connection to *basic statistics* from middle school mathematics. From middle school mathematics, the students learn the basics of probability by working with histograms. As an application, in image processing histograms are used for counting the number of occurrences of each gray-scale intensity. Then, for example, brighter objects can be identified as a histogram peak associated with high values. To work with the images, the engineering team suggested the use of Matlab, the de-facto standard platform for Computational Sciences and Engineering (Strang 2007). Overall, image and video processing provided an interactive and visual context for understanding, applying, and extending middle school mathematics. It afforded students opportunities to be creative while using mathematics and programming.

There are significant differences in the expectations between the engineering and the middle school mathematics. In engineering, there is a focus on high expectations, where the students are supposed to *learn by doing*. The rich body of literature on mathematics education provided a culturally responsive framework (Moschkovich and Nelson-Barber 2009) for adopting the engineering content into an integrated curriculum that taught content based on its middle school mathematical foundations. In addition, there was a strong engineering and mathematics focus on *problem solving* as well as a strong focus on the pedagogical perspective to content knowledge. We present results of our collaboration in designing an integrated curriculum in the next section.

Results of our collaboration with an integrated curricular task

As shown in Figure 2, one of the fundamental concepts included in our curriculum was the basic structure of digital black and white—binary—images. This concept was included in session 2 of our curriculum. In this session, our goal was to support students' understanding of how these images are created, understood by and input into a computer. For this, we made use of the coordinate system to represent how this grid of points lays out in detail the shape of an image. Each point in the coordinate system—or square from the grid—represents a pixel or the smallest unit of an image. In the case of binary images, these pixels may be either white or black; color variable which is indexed respectively by using the values 0 or 1. Thus, we wanted our students to conceptualize a binary image as a grid of zeros and ones or a coordinated system composed of organized values.

Figure 2: Session 2 task demonstrating the integration of image processing content—engineering—with middle school mathematics



These concepts, fundamental to image representation, are closely aligned with mathematical concepts that students need to learn in school mathematics. The task, presented in Figure 2, relates to specific Domains and Standards described in the Common

Core State Standards for Mathematics (National Governors Association Center for Best Practices 2010), which have been adopted by the state of New Mexico. The related Standards include the following. For the 6th grade Number System Domain standard number 8—6.NS.8—it is stated that students are to solve real world and mathematical problems by graphing points in the coordinate plane. Similarly, for the 6th and 8th grades Domains of Expressions and Equations describe that students need to learn how to read, write, and evaluate expressions in which letters stand for numbers or in our case numbers stand for colors and for pixels—6.EE.2a, 2c—generate equivalent numerical equations—8.EE.1—and understand that a function is a rule that assigns to each input a specific output—8.F.1, 2, 4. Additionally, this task also relates to High School Standards of Geometry by having students express geometric properties with equations—G.GPE.7—and model with geometry—G.MG.3.

In order to introduce the embedded concepts, the task was designed in a context with processes founded on a sociocultural perspective. This context was characterized by the inclusion of processes embedded in the students' activity that would support students' interaction, communication, and abstraction of ideas related to the representation of binary images. For these purposes, the task was planned in the following stages:

a) *Own design*: The task started with students' input and own creations. Students were asked to develop design of a binary image in a 20 by 20-pixel matrix. The main instructions at this stage were: "In the 20 x 20 matrix shown below, create any figure by filling in complete squares with black."
b) *Active sharing of design*: After students developed their own design, they were asked to share their ideas with a partner, but the sharing included a "hidden" process or message because students were not to share the image that they designed directly, but they would provide instructions to their partner, so the partner would follow instructions provided by the student who designed the targeted image. The goal was not only to share the image, but also to provide a context where communicative processes were necessary to produce an expected outcome. The quality of communication—expressive and receptive—matter in the sharing of the design. The instructions stated: "Find a partner and ask your partner to find a similar sheet of paper with the 20 x 20 matrix; then tell your partner the location of each square you filled in. The goal is that your partner fills in with black as many squares as needed based on your directions and without letting your partner see your design."
c) *Use of a specific code*: The communicative process was constrained by the use of a specific code or discourse that would allow students to provide precise instructions to their partner. This process also provided a meaningful rehearsal of the decoding and encoding of the image that the students had designed. Students were required to name each pixel by using the X and Y points that located its exact location. For example, '3R-13C' where "R" represents the number of row and "C" represents the number of column. The instructions stated: "To name a shaded square that you filled in, you need to name the numbers that intersect at that point." This process eventually also pushed students to realize that describing clusters of pixels rather than telling pixel by pixel would ease the process of communicating and drawing the image.
d) *Receptive sharing of someone else's design*: Students were asked to switch roles after having shared and corroborated their design with their partner. This shift helped

students to rehearse their receptive understanding of their peers' decoding of their image and an active encoding of that same image.

e) *Use of computer codes and commands*: Finally, students were provided with the commands that would allow them to tell the computer or represent their designs and other binary images by using high-level computer software utilizing MATLAB. The instructions, among other details, stated: "Use the following MATLAB commands to create a black square, of size 5 x 5, inside a 20 x 20 matrix."

These steps include a fusion of engineering and mathematical concepts embedded in a pedagogical context, social space founded on sociocultural principles (Vygotsky 1978). This space promotes the understanding of mathematical and engineering concepts through mathematical thinking processes such as problem solving, reasoning, communication, representations, and connections (NCTM 2000), and which supports the appropriation of mathematical (Moschkovich 2004) and engineering practices.

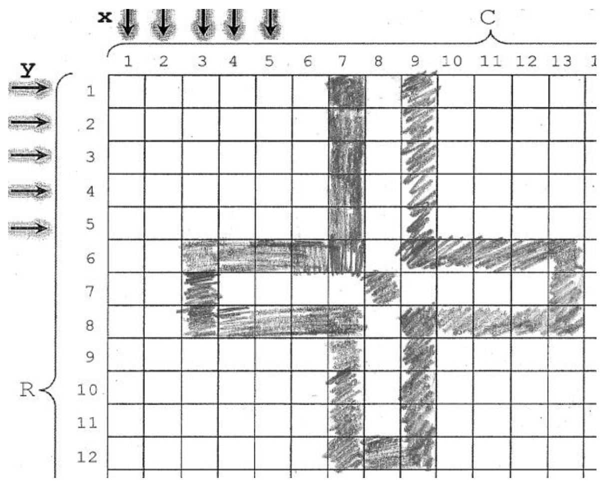
To illustrate the kind of interaction, communication, and abstraction developed among students through the frame that this task supported, we present the work of a group of students by using data we gathered through facilitators' fieldnotes and student work. This example provides insights about how students collaborated and engaged with this session conceptual ideas moving from using paper and pencil tasks to programming using MATLAB.

Students successfully engaged in the process of designing and communicating their images to each other by deconstructing and encoding these images at the pixel level. During the communication of their images, students chunked the images into clusters of pixels, a process which not only eased the communication but which also served as a strong foundation for the construction of their MATLAB commands. The excerpts below show how a group of students communicated their images to one another:

Craig: We can just tell each other what coordinates to draw.
Paco: (to Juan) Okay… 2 to 4 on 5… and 5 to 7 on 8
Craig: (to Sam) Do 7, 15…(checked to see if he colored it in) 8, 15… 9, 15… 10, 13… 10, 14… 10, 15.
Juan: (to Paco)- OK, row 6 from 3 to 7, and also 6 from 9 to 13. Then 8 also from 3 to 7 and 8 from 9 to 13. So there is a gap in between row 6 and 8, right? Now, on row 7 mark 3, 6, and 13. Then from rows 1 to 5 and 9 to 12 down on column 7, and also from 1 to 5 and 9 to 12 on column 9. Again there is a space between columns 7 and 9 except on row 8. Oh! And also mark 12, 8. (June 2012)

Juan precisely described and communicated his design, included in Figure 3 below, to his partner, Paco. This precision was achieved by purposefully communicating his image design without sharing the actual image, but only providing oral input. This process seemed engaging to both students in the process of decoding and encoding the same image and served as a transition into creating their codes using MATLAB. When students used the computer to enter the commands, their attention centered more easily on the syntax of the commands, but the conceptual understanding of the encoding of the image was already a shared understanding for the students. The paper and pencil task was critical to developing a conceptual understanding of the computer-based task.

Figure 3: Paco's binary image design



The excerpt below from the same group describes how students collaborated in the generation of MATLAB commands that would efficiently run an image of the design that they had. Notice that students' concerns in developing their commands were not about the encoding or generation of the image itself, but on the specifics of the computer commands that would accurately represent their image. This process is important as students engage in the mathematical practice of attending to precision and as they begin to appropriate language that integrates mathematics and programming.

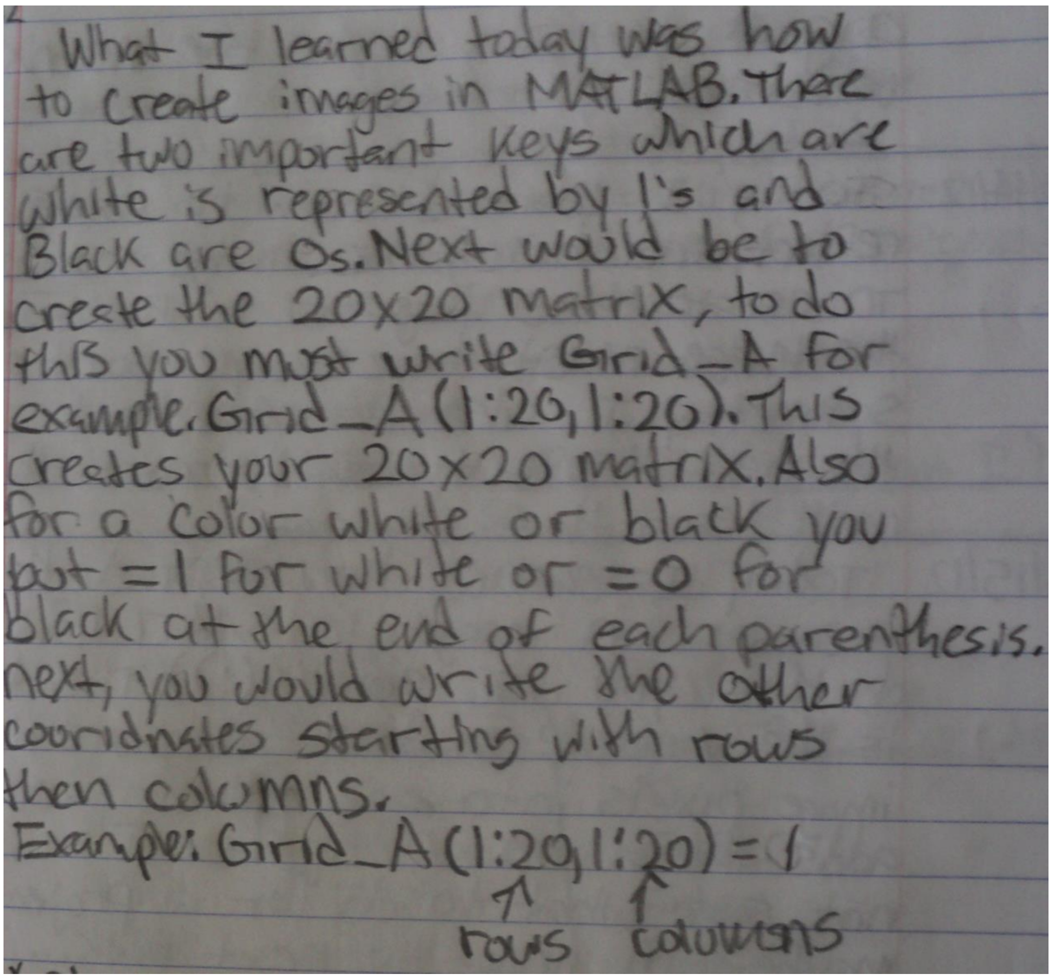
Sam: OK, we got the 20 by 20 grid. How are we going to get the 5 by 5 box in the picture?
Craig: Well, how did we tell each other where to put the box?
Juan: Tell the computer 5 to 9 and 5 to 9.
Paco: But we need to change the color or it will be white and we won't see it.

Students demonstrated a solid conceptual understanding of the general process of image representation, and their discussions targeted details about how the computer was to process these commands. Paco's interjection supports his awareness that, as in paper, you shade with a pencil the squares that delineate your image and that in MATLAB you need to "color" the image as well. Students were familiarizing themselves with how this technology works. In our view, it seems as if students wanted to understand the computer in a more intuitive way as they understood the process of representing and designing an image, but in the use of commands the computer has a very restrictive frame of input which students found limiting at times. The facilitator in the same group described above mentioned:

> The group had a very hard time figuring out how to display the picture. The group read the directions, but didn't really follow directions. They looked for a specific command and copied it as such on their MATLAB script to see the picture. (June 2012)

Students often would misspell a word or command and, although they had understood the process conceptually, the typing seemed to be in the way and at times it became frustrating to them to need to be perfectly precise in their typing of commands. Furthermore, based on this need to pay great attention to detail, at times students, in order to prevent errors, wanted to directly copy commands from the guidelines, thus reducing the process to a memorization of procedures without understanding. Our goal as a team, however, is that these students engage in image representation using computers through a process that supports students' reasoning and conceptual understanding of the tasks. Figure 4 below shows an excerpt from Paco's journal where he mentioned what he learned during this session at A-OLME.

Figure 4: Paco's journal entry describing what he learned during session 2


What I learned today was how
to create images in MATLAB. There
are two important keys which are
white is represented by 1's and
Black are 0s. Next would be to
creste the 20x20 matrix, to do
this you must write Grid_A for
example. Grid_A(1:20,1:20). This
creates your 20x20 matrix. Also
for a color white or black you
put =1 for white or =0 for
black at the end of each parenthesis.
next, you would write the other
cooridnates starting with rows
then columns.
Example: Grid_A(1:20,1:20) = 1
rows columns

In this excerpt, we see Paco telling us that he learned in an integrated way. He did not necessarily separate conceptually what he had done in paper and pencil from what he did on the computer. He integrated these processes into one category, "Creating images in MATLAB". We believe that movement between paper-and-pencil as computer-based tasks is useful and necessary, but still our goal and challenge as a team is to develop tasks and interactions with students that support their reasoning and conceptual understanding of the mathematical and engineering topics that we include in both contexts through problem solving, either when students are using computers or not. The value of *mutual respect,* which we highlighted as foundational in our collaboration, is also central in our interaction and work with students. We acknowledge the need to use and build off from what students know and what they have told us, directly or indirectly, that is successful to them in the process of understanding digital image representation and processing. We agree with what the facilitator working with Paco's group wrote in his field notes: "*It was great for me to step completely and let the students learn on their own. They seemed reluctant at first, but gained confidence as the session progressed*." We recognize that we are just starting to understand the learning and teaching of middle school students in this integrated approach.

Discussion

The basic need associated with educating middle school students from underrepresented groups *does not respect the traditional boundaries between education and engineering disciplines.* An interdisciplinary collaboration between engineering and mathematics/bilingual educators is needed to address the issues. This paper's presentation of a collaborative interdisciplinary effort founded on mutual respect provided a basic framework on how to address some of the issues.

We advocate that *engineering education be built on current middle school mathematics*. This provides a well-understood foundation for middle school engineering education that is currently lacking. Furthermore, by building engineering education on mathematics education, we have a strong and diverse body of educators who can be educated on how to implement the curriculum. In terms of the curriculum that was developed as part of A-OLME, we note that the pencil-and-paper tasks did not require access to computers but are complementary to computer-based activities, and they can be integrated into everyday mathematical tasks provided to students in the classroom.

On the other hand, teaching programming to middle school students does require specialized professional development for teachers that is currently lacking. We hope that the A-OLME pencil-and-paper tasks and computer-based tasks that promote reasoning and understanding through problem solving will help bridge the gap between current middle school mathematics content and basic programming skills. Our hope is that mathematics/bilingual educators working with the basic image and video processing tasks will find the transition to programming easier through our insights as a platform on which to build on. Furthermore, by working with digital images and video, we expect that students may be motivated and supported to see themselves as doers of mathematics and incipient members of the community of programmers and processers of images, so that they may choose to remain in the field at the college and professional level.

More generally, we believe that the teaching practices in mathematics/bilingual education can be used to inform engineering education at all levels of K-12, not only middle school levels. Integration of engineering tasks into the teaching of mathematics will help make engineering more accessible and mathematics become more relevant to technological advances.

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