IMPLICATIONS FOR MATHEMATICAL ENGAGEMENT WHEN EVERYONE HAS IPADS IN THE CLASSROOM: THE GOOD, THE BAD, AND THE UGLY

Erica Johnson, Ryan Gantner, Kris Green, and Mark McKinzie

St. John Fisher University

3690 East Avenue

Rochester, NY 14618

ejohnson@sjf.edu, rgantner@sjf.edu, kgreen@sjf.edu, mmckinzie@sjf.edu

Introduction and Context

The authors speak to these trends through the lens of their own experiences. To do that, some background is necessary to become familiar with what the authors' experiences are so that the reader can align them with their own situation. The authors form the mathematics faculty at St. John Fisher University, which has an enrollment of approximately 2700 undergraduate students, and is located in suburban Rochester, NY. The University prides itself on small classes; all math courses are less than 35, most are less than 22. Students primarily matriculate from New York state.

One technological piece that profoundly impacts our experience is the iFisher: Next Generation Learning Initiative. Through this program, St. John Fisher has invested resources to have a 1-1 iPad program. This means that all faculty and students currently have an iPad for their use, as well as an Apple Pencil. The initiative began in summer 2021, when all faculty were given iPads. The institution offers a two-part Apple Academy training program, including the option to become a Certified Apple Teacher. To date more than 270 current and former faculty members who participated in the Fisher Apple Academy training became Certified Apple Teachers. Opportunities for continued faculty development are available through the DePeters Family Center for Innovation and Teaching Excellence. Beginning in fall 2022, all Fisher students have iPads and use them in varying ways. Fisher was recognized as an Apple Distinguished Scholar for 2022-2025. St. John Fisher University has made using classroom technology relatively easy. All of our classrooms have features that include computer projection systems, Apple TV systems (so students and faculty can quickly connect their iPads to the classroom projectors), and document cameras that can display documents as well as capture nearby audio.

During the pandemic, faculty used the iPad in tandem with Zoom to hold class remotely or project notes in the classroom. Once we returned to the classroom after the shutdown, many faculty used iPads together with Zoom in the classroom to project the class, share with remote students, and to create a recording of the class contents. The iPad was used either as a primary or a secondary device, from which the instructor could project lecture notes

onto the screen for the class and the remote students to see simultaneously. Over time this usage has changed, developed, and is continually being reimagined.

Consequently, there are myriad ways in which mathematics faculty and student use of iPads has transformed the classroom experience. In this paper, we will showcase how the mathematics faculty leverage technology to support student understanding. Not only do we get the opportunity to share what is happening in our classrooms, our engagements often lead to new ideas and inspirations that we can incorporate to enhance what we are doing in our own classrooms. As we compared notes on how we are using the iPads, often in conjunction with other technologies, several patterns emerged. Big categories like course organization and management, communication and assessment, class engagement and dialogue, and developing utility with expected and unexpected technologies are presented. We have identified pros and cons and some potential pathways going forward.

THE GOOD

Course management and Organization

Teamwork makes the dreamwork, and as it often is with iPad usage, the iPad may be the vehicle, but it is the collaboration between technologies that is the real star of the show. At St. John Fisher, Brightspace is used as a learning management system. The technological features of Brightspace lend itself to be used in tandem with the iPad for course management, organization, and assessment. Additionally, faculty members use Google products to support student learning. Faculty use the Google Drive to share Google (and other) documents with students. Course materials can be posted in Brightspace, organized by week, with materials posted as they are needed. Each of Erica Johnson's courses has a shared course folder in the Google Drive containing course materials posted in Brightspace, as well as materials without a link in Brightspace. Google documents, where students can edit in real time, are used for group work so that a record of the problem solutions is created.

Amongst the many fine supporting apps, one of the most versatile is Notability because of the power to create support materials for class – either notes to supplement class discussions, starters and prompts for discovery or discussion, or group work activities for class. Notability is an amazing tool for both teachers and students. The user can scan the image or pdf into Notability, add annotation, highlight important information, and easily share the final result. This really came to life for Erica Johnson as she was constructing a Geometry lesson on the protractor postulate and the connections between the protractor postulate and ruler postulate. She had scanned all the pages, but the order took a few iterations to get to. Using the Notability app, it was easy to move things around until the right order emerged. To get things from the instructor to the students, the instructor scans an image into Notability, where they can edit and save to the Google drive as a pdf or Google document. Creating a link to the file and posting it in Brightspace makes student access to course materials easy.

Assessment and Communication

The interplay between the iPad and Brightspace is especially nice when using the assignment feature. Through Brightspace, the iPad and Apple Pencil make it relatively simple to markup student work that is submitted electronically. The instructor can write directly on the PDF that students submit. Several faculty members collect assignments and give exams and quizzes electronically. Students can use the Notability app on the iPad to create their homework or to complete quizzes and exams. The process is like the instructor sharing course materials. Students download the assignment, import it into Notability to complete their work. They can save a copy of their work as a PDF file and upload that file directly to Brightspace. Faculty can grade directly in Brightspace by using a comment box to provide feedback or they can write directly on the student's electronic submission by using the Apple Pencil. Brightspace also has handwriting recognition so faculty can handwrite student feedback, and it gets converted to something legible with minimal editing necessary. This assessment feature was especially helpful in grading poster presentations in a Statistics course where Kris Green was able to set up a rubric for the posters ahead of time. Using the iPad with the Apple pencil allowed him to seamlessly move from student to student, recording evaluations and writing feedback to them in real time during the poster presentations.

A natural question emerges about what resources students may be using during a quiz or an exam. At Fisher, we use the Apple product called the Classroom app that allows the instructor to view students' screens or restrict usage to a particular application or applications, which, in theory, will keep the students honest. The Classroom app is more than just an electronic proctor. Some faculty use the app to connect and communicate with their students, or to distribute assignments or course materials or to help guide the activities of a particular class. The instructor can share course materials with the students or guide them through activities. Students can submit work to the instructor as well. In addition to displaying active apps for each student, it also has the capacity to record a summary of the students' activities. Some faculty find the capabilities of this app somewhat intrusive and avoid it. The Classroom app is relatively easy to set up. Teachers can add students to a course directly or share a code with their class that allows students to join. It does not take long to set up and once the class is set up, the instructor should not have to set up the class again.

Dialogue, Demonstrations, and Classroom Engagement

When every student has an iPad, every classroom, or indeed any space, becomes a computer lab. It is remarkable how students can access course materials posted in Brightspace and download them into Notability so that they can annotate and integrate into their notes. Students have access to mathematics apps and websites at their fingertips. They may not always use it in productive ways, but it is there. Students use the iPads to

give presentations in class and on their experiential experiences like internships and undergraduate research. It is easier to connect to the class projection system than a laptop, as no cables are required. Students also use their devices when they study together and discuss their coursework out of class.

Room projectors and Apple TV make it easy for students to share their iPad screen where they have work either in a Google document or in the Notability app. Notability presentations are especially fabulous because the student can (literally) highlight important concepts and edit as necessary during the course of the conversation. In Erica Johnson's Geometry course, students gave presentations involving complex geometric images, in which they used the highlighter feature to elucidate the important relationships between angles and rays. The way students discuss their work and mathematical ideas in the moment is absolute joy! Sometimes students in courses that are not required for the math major are less willing to share their work with the class, but even students in these non-major courses are getting in on the action. Because students present from their seat using their device and the Apple TV projection system, more students are sharing their work in these classrooms. Not having to go to the front of the room makes a difference!

Google docs and Google Sheets make class collaboration, group work, student sharing work with each other and the rest of the class using the iPad easy. For example, the students in an upper level Real Analysis class have been using the iPad to streamline the course. Ryan Gantner teaches that course using a presentation-style Inquiry-Based Learning (IBL) approach. Inquiry-Based Learning approaches are characterized by engaging students in meaningful mathematics, student collaboration, instructor inquiry into student thinking, and conscious equitable instructional practices (see Laursen and Rasmussen, https://eric.ed.gov/?id=EJ1210552). One way to bring out these characteristics is to have students present proofs to the class.

Writing the proofs on the iPad has several advantages. First, the proof can be brought up in front of the class instantaneously via Apple TV, rather than having the students write their work on the board. Not only does this save class time, but it also allows students to print their work in a more relaxed manner, allowing the student to take care and perhaps affording better penmanship. When students present their work, the instructor's job is often to slow down the presentation so that the class can digest what is being presented. This also, unintentionally, brings about presentation skills for the students. Most importantly, however, the presenter is able to edit their work on the fly according to the discussion of the class. Their work is easily moved, erased, copied, or molded to facilitate corrections to their proof. Due to the nature of the class, most of the corrections that can be made on the fly are along the lines of making the hypotheses clearer, adjusting quantifiers for variables, adding justifications, etc. – all maneuvers that can be accomplished by moving text around using an app such as Notability. We can also immediately bring up versions of the proof completed by other students for comparison, something that would be difficult to recreate using the board.

Accessibility and Inclusivity

Google products are useful on the sharing front. Students in Erica Johnson's class use a Google document to record their tries on suggested problems to guide the discussion in the upcoming class. Whether students use an app like Notability or pencil and paper, the students upload an image of their tries into a Google document that is shared with the instructor. By using a Google document, students can update through the progression of the semester and can easily share their work from their seat whether they used paper and pencil or an app like Notability. Not all students have the same technical skills, but we can support their technological growth by allowing them to use the platform of their choice and encouraging development in others through the term. It can be difficult for students to get all the notes from class conversations, so some faculty create a student sharing folder in the class Google Drive so that the presenting student can upload a screenshot of their work, sharing it with the rest of the class. The iPad makes this process relatively easy. Students are often in different places in their learning journey. Creating space for them to use their preferred technologies and the opportunity to get supporting notes in a timely manner can support student learning.

Additionally, a colleague with physical limitations is unable to stand during an entire class period. Over time, he has used a variety of technologies to run class from a sitting position. He started with a tablet that he connected to the projector to display the screen but strongly favors the iPad as it means he can run class while sitting – allowing him to make eye contact with each of his students and otherwise engage them at their level. The ease of the Apple TV projection system is not just a boon for the students; it also allows faculty to make extensive use of the iPad integrated with other technologies - depending on the needs of the specific class.

iPad integrated with Expected and Unexpected technologies:

All faculty have used technologies that one might expect like MyOpenMath (www.myopenmath.com) and Desmos (www.Desmos.com) in precalculus and the Calculus sequence. Both technologies are popular with students and faculty alike. Desmos is easy to use for beginners and MyOpenMath offers a variety of support options. Both work well on the iPad. It was the unexpected technologies that were noteworthy. Kris Green uses the iPad to support programming in Python in both his Mathematical Statistics and Numerical Methods courses, and Ryan Gantner uses the website districtr.org in an Honors course.

Programming in Python is often done by installing programs on a computer, such as Jupyter Notebook. This poses a potential obstacle to programming on the iPad. However, we have found that using Google Colab as a programming environment is more than adequate for an introductory programming experience. This includes courses such as numerical analysis or linear algebra where programming may be a part of the course but not the primary learning goal. Google Colab does not require the student to install anything and

makes it easy to share work. Indeed, sharing works the same way as any Google product does, which also makes the work easy for the instructor to leave comments on the work and to run the code which has been submitted. Through the iPad, students can easily access this cloud-based computing platform, and it is straightforward to share their work with the instructor or access code that is shared with them. This makes evaluating work much easier than sending files around or needing to compile them, and it ensures that both the instructor and the students are working in the same environment with the same packages, etc.

Ryan Gantner had the opportunity to co-teach one of a pair of courses in Fisher's Learning Community program. Aimed at freshmen, the Learning Community courses aim to build community among students, make progress toward the schoolwide learning goals, develop study skills and habits, and develop interesting perspectives on multidisciplinary topics. The course Ryan taught was about math and politics, co-taught with a political science professor. One of the units in the course was about gerrymandering. What is it? How do we detect it? How can we quantify it? The class first discussed looking at the shapes of political districts to identify gerrymanders. Students used iPads to help calculate perimeter and area political districts as well as bounding boxes or circumscribing circles. These quantities are used in various shape-based metrics for gerrymandering. Next, the students discovered that shapes cannot tell the entire story: some justifiable districting plans can have awkward shapes and some plans that have compact shapes produce results that are often flagged as gerrymanders. Therefore, the demographics of the district must be taken into account. One fantastic way to have the students wrestle with these issues is to have them draw their own districts using actual geographical, population, and demographic data from the United States. This can be done easily, especially with the iPad, using the website districtr.org. Using this app, students can use the Apple Pencil to color proposed districting plans in a given state down to the level of voting precinct. The demographic and population information automatically populates and can be compared. Election information is also loaded, so one can compare how these hypothetical districts may have voted. With the iPad, this is very easy – it's like coloring in a coloring book. This helps keep the activity light and enjoyable for the students. Capturing geometric information from these hypothetical districts can be somewhat difficult, but progress is being made on that front (see the "Going Forward" section below).

Additionally, the website davesredistricting.org does similar work, but is more powerful. Dave's Redistricting is used by actual mapmakers to draw political districts. This has the advantage of being able to download snapshots of hypothetical districts and compute basic shape-based metrics. It also has more detailed demographic information. However, Dave's Redistricting website doesn't work with the Apple Pencil. And it requires a (free) login, which is a bit of a pain for some students. Finally, the geographic information on the website is so detailed that the website can grind the iPad to a halt if one is looking at dividing a large state into many districts - such as the Texas state house, for example.

When students have the skills

Faculty learn as much from the students as they did from the Apple training sessions – which were great. It is just that the students know what they are doing and like to share their knowledge! Furthermore, their suggestions tend to be specific to mathematics and supporting a mathematics classroom. And they know of what they speak. Some of the students have been using iPad (or tablet) technology since they were (literally) children. Students share their expertise in and out of class - with their instructors and the other students. In turn, the faculty share those suggestions with other students.

THE BAD:

Technology, amirite? It does not always work and can behave badly, which means that actual mileage may vary. For example, Erica Johnson was never able to get the Classroom App to work reliably, and it took way too much class time to ultimately not work. Also, iPad usage really seems to slow students down. This is true in several ways, and it impacts the students with the least iPad experience the most. Even the strong (iPad) students spent a fair amount of time moving things around and making everything look neat in the process of taking notes. A reasonable reaction is to think that it is good to slow things down a bit in class. In this case, instead of thinking about the content, they are worried about formatting and visual appeal, making it easy to fall behind the group conversation in class.

Even though class was organized by the week, students do not always know what week of the semester it is. As recently as the week before spring break (7th week of classes) students still weren't sure where "we were at" in Brightspace. Making sure that everyone knows where we are at and what we are doing is an easy way to foster inclusiveness and catching students up gives class a chance to slow down. Students can get used to having notes provided and sometimes seem surprised when we try to do something from the document camera or the board and they have to write an example down.

Sometimes the iPad is poorly behaved and lest this becomes a laundry list of technological shortcomings of a specific personal device, we will focus on troubleshooting, workarounds, and real problems when encountering technology. Erica Johnson's iPad device had several idiosyncratic trouble spots. The most persistent problem being the scanning feature in Notability. Unfortunately, it did not work reliably. Over time, several work-arounds were developed but it remained a persistent issue. One of the ICTCM 2025 audience members suggested using the Scanner app that comes built-in to the iPad. As far as we know this was not an issue for any Fisher students, but it was noticed in the MyOpenMath discussion board that some students at other institutions were having issues using MyOpenMath with the iPads. The work around was to use the web browser rather than the app. This was a common work around as the same was recommended for Microsoft Excel on the iPad. The Apple app (Numbers) doesn't support some of the standard spreadsheet features but instructors who taught data analytics courses had better luck with the web-based version of Google Sheets.

One Python problem encountered by Kris Green was that a few things did not work well in Colab, particularly with 3-dimensional plots, animations, and other interactive elements. Furthermore, the incorporation of generative AI into Google Colab has added a new challenge in using Google Colab. This feature is built into the system and will make extensive suggestions for code to use. Interestingly, it often not only makes reasonable suggestions for how to code a particular simulation or computation, but it often seems to make good guesses at the values of the variables that match the problem we are working on! Presumably this works so well because there are people in several institutions using Google Colab for similar purposes at about the same point in time during the semester, so the AI has many examples from which to draw, allowing it to recognize shared patterns across these instances.

Other potential downsides are that because Colab is a cloud-based platform, using it to examine datasets requires either uploading the data to the cloud or giving Colab permission to peek into one's Google Drive, neither of which are entirely straightforward. There are also practical runtime limits that will render this unable to do serious data crunching. However, this was never going to happen with an iPad anyway, so it seems that Colab is a fine way to allow students to do real computer programming with the iPad.

THE UGLY:

There are always downsides to a distraction box. Some students use technology in fruitful ways whereas other students are more distracted. This is true even of good students. When you check your email during class, you are missing important information. Young people often think (falsely) that they can multi-task.

Unfortunately, allowing access to the internet during assessments means that it is easy for students to use resources that they aren't allowed - even in good faith! There were repeated incidents of cheating and also students who (unintentionally) used technology in ways that were not intended by the instructor. For example, one professor allowed access to certain technologies not including AI, but the student takeaway was that AI was included in the allowable resources. Another professor had a student misunderstanding related to the use of Desmos.

Not all students have the skills and that creates inequities in student access and success as well as general preparedness. Lost chargers and broken Apple pencils mean that sometimes students are taking notes with their fingers. And that is definitely slowing them down. We encourage students to use a combination of technologies. For example, when students use their fingers, we try to get them to use pencil and paper. Or more generally, we encourage students to use their favored combination of technologies. It seems to be working more as it is becoming more common for students to bring and use two devices or to use a pencil and paper along with their iPad. Occasionally, students believe that they need to use the iPad exclusively or that using the iPad affects their grade. It came up

recently that a student thought that iPad use was tied to their grade, when in fact, we want them to use whatever technology they feel comfortable with. While materials are displayed on the board, it can be a detriment if they have to continue to look back and forth from the board to their paper. Many students with multiple devices will view the notes from a device and work with pen and paper.

Lastly, the literature surrounding the impact of devices on student understanding and learning is mixed. While the devices provide many benefits, including those articulated in this paper, the drawbacks are substantial. Distraction is a drawback that is commonly cited as a reason to be cautious about using devices in the classroom (Rosen, 2008). For further discussion, see Nabung 2024 or Valverde-Borrosco, et al. 2022 and references therein.

Going Forward

Practicalities, positives, and problems have been posited. The iPads are here, and they are not going anywhere so our objectives are to lean into things we like and refining as needed. To varying degrees, faculty are looking into ways to assess so that students learn to use technology appropriately. Some of us are not allowing any communication devices on exams and others are relying on the Classroom app to help keep away the temptation to use inappropriate resources.

The iPad and its related/interconnected technologies will continue to change, evolve, and improve. Every instructor will interpret facets of the technology that they deem helpful and facets that they deem harmful. Generally speaking, the most helpful facets tend to be the ones that increase collaboration (Google Suite products, screen sharing abilities, etc.), that automate or simplify complicated tasks (Colab, LMS tools, etc.), that increase accessibility (allowing computation ability everywhere, Notability, etc.), or those that afford elucidating complicated topics (Desmos, districtr.org, etc.). Harmful facets come from the distraction that these technologies produce, the uneven abilities to use the technology among students and faculty, and the overhead spent in learning to use the technology appropriately.

As the landscape evolves, we must focus on ways in which the positive aspects can be leveraged while minimizing the negative aspects. For instance, Google Suite allows for creating and sharing documents in a collaborative way, but the conventions surrounding saving (file folders and structure) are not intuitive to many students and not as easy to navigate as many would like. Thus, students sometimes have a difficult time locating the materials they need from their cloud storage location. A little bit of investment in ways to help (talking about file structure, naming conventions that will improve one's ability to search for a file later on, etc.) can help students throughout their college experience.

Thus, moving forward in a landscape where everyone has iPads, we focus on the helpful facets. For instance, in thinking about collaboration, Erica Johnson's current focus is trying

to create a more inclusive classroom by improving the quality of the group work experience – both in terms of the tasks themselves and the formality of the task engagement. Ryan Gantner's focus moving forward for his course on Redistricting is an app which simplifies the computational aspects of the quantification of gerrymandering by automatically computing geometric properties. Such an app would allow the user to upload an image of a political district and have geometrical quantities such as area and perimeter calculated automatically. The student can then use the results to calculate various shape-based gerrymandering metrics. Students will also be able to draw bounding boxes, circumscribed and inscribed circles, polygons (convex hulls) and more and access their geometric properties in order to analyze and compare both the district (using different shape-based gerrymandering metrics) and the metrics themselves.

Clearly the engaging class dynamics need to stay so creating more opportunities for students to share their work and ideas will continue. With iPads, it is easy for students to upload their work, making the relative ease of student to student or student to class sharing is hard to beat. That students can present from their seats means they are more willing to share their work with the whole class.

Another area targeted for improvement is to try to bring more inclusiveness to the classroom by increasing digital equity. We hope to be able to approach this on two fronts. First our own classrooms, and second, possibly through the Writing and Tutoring Center. It can be easy to more-or-less assume that students can do the computer tasks required in our courses (e.g., creating and naming files, saving them in a way that we can ready, uploading them to the learning management system, downloading the files that the instructor posts to a location they can recover as needed, viewing posted files) but the practical reality is that many of the students simply do not have this background knowledge. Creating and posting an instruction sheet can help but it is not enough. In Erica Johnson's class, students create and share a (Preparation task) document that they share with her during class. Between the instructor and their tablemates, students less familiar with the iPad are able to get support in the moment. Getting confirmation that it has been received help to assuage any student concerns. We continue in this tradition to make sure everyone is caught up, knows where we are, and has access to the appropriate course materials.

This approach can be adapted and continued for as long as necessary. Building this into the community and group norms conversations can also help. Erica Johnson has been in conversations with the director of the Writing and Tutoring Center about supporting students' digital literacy with peer tutoring. As with most things, this will be dependent on financial support which has not yet been guaranteed, but as we are able to move forward, we hope to create peer-to-peer digital support and mentoring, utilizing the expertise of those students well versed in iPad usage.

In closing, we invite you to continue the conversation. Kindly send an email with your name and email to any of our co-authors that you would like to follow up with.

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