

THE EFFECTS ON LEARNING FOR THE HIGH SCHOOL BIOLOGY STUDENT
WITH THE IMPLEMENTATION OF THE INDIVIDUAL iPad USAGE
IN THE CLASSROOM

by

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ABSTRACT

The purpose of this project was to investigate the introduction of the individual Apple iPad to the high school biology student, establishing the one-to-one classroom, from the perspectives of the students, their parents, and the science department teachers. A series of surveys were given to the students in two classes at the beginning and end of the school year, as well as midway through the fall and spring semesters. Student responses were sought for opinions on the impact of the iPad on organization, homework completion, test preparation, extended individual pursuit of topical class information, and the possibility of distractions. Twelve individual student interviews were also undertaken to elicit extended, candid responses to related questions. Parent surveys were administered to gauge familiarity with the device and estimate of their child's school experience and productivity due to the presence of the iPad. Departmental science teachers were surveyed to investigate opinions on their overview of the program, professional fulfillment from the program, challenges confronted, and possible enhancement of student learning outcomes in light of introduction of the device. The collected data suggested increased homework completion, perceived better test preparation, and reading assignment participation for the students. Distractions due to game playing were a real challenge in this initial year of the program, as noted by students, parents, and teachers. Due in part to this challenge, levels of teacher frustration were reported as higher, with personal fulfillment possibly diminished. Nevertheless, with more practice, future positive outcomes are believed to be possible in differentiated instruction, student engagement in school, and the further integration of technology into the science laboratory.

INTRODUCTION AND BACKGROUND

Starting with the fall semester, 2013, every student was required to purchase an Apple iPad and bring the computing device to each class for daily use. It is the belief of the school administration that the introduction of individual iPad utilization, or the one-to-one classroom, will lead to better student learning. Our school, Christian Brothers High School (CBHS), located in Sacramento, California, serves just over 1,000 students, divided almost equally between females and males (cbhs-sacramento.org, 2014). As of the 2013-2014 academic year, there was no ethnic majority with 48% Caucasian, 23% Hispanic/Latino, 8% Multi-Racial, 7% African-American, 7% Asian-American, 4% Pacific Islander, 3% Native American (Jan Warren, CBHS Registrar, email communication, November 21, 2013). Thirty-five percent of the students receive financial assistance to offset at least a portion of the \$12,500 annual tuition with the average scholarship award being \$5,500 (Kenny Kirrene, Director of Admissions, CBHS, personal communication, March 19, 2013). In the tradition of its founder, John Baptist de La Salle, CBHS is very intentional not only in the diverse financial wherewithal of the students' families, but also their academic abilities. The administrative goal for each incoming freshman class is to be as academically balanced as possible among the accelerated student, middle level (termed college preparatory), and fundamental, based upon the student's entrance examination prior to admission. My college preparatory biology classes consist of a fairly broad range of students, basically encompassing the middle and fundamental students.

Three years ago, the school administration made the decision to transition from a traditional lecture and note taking classroom environment to the one-to-one classroom in

the fall of 2013. The faculty were issued personal iPads at the start of the 2012-2013 school year and there has been a smattering of short professional development sessions to orient our faculty in its basic utilization. Beyond the mandate that we will be using the Notability application for all classes as a common notation method, the manner in which the teachers utilize the iPad is up to individual discretion. As we approached the fall semester introduction of the iPad, I must admit to having felt more than a little apprehension about my ability to proficiently navigate the personal computing device, all the while trying to maintain order and a coherent classroom. Further, it was my belief that many of the students were also experiencing varying degrees of trepidation during their adjustment to the one-to-one classroom.

This has led to the creation of my focus statement, what will be the effect on my biology student learning performance with the new one-to-one classroom as compared to the traditional classroom? In addition, the following sub-questions were researched.

1. What are my students pre-existing opinions and self-assessments of their organizational skills and technology preferences?
2. What are the school parents' views on the implementation of the iPad in the classroom?
3. What will be the students' academic performance in the one-to-one classroom as compared to the previous year's traditional classroom?
4. What will be my personal response and adjustments to the one-to-one classroom?
5. What will be the opinions of the teachers in our science department to the initial year in the one-to-one classroom?

CONCEPTUAL FRAMEWORK

The one-to-one classroom is an outgrowth of the availability and desirability for current technologies. A working definition of the one-to-one classroom is simply to provide every student with a portable computer for use both in the classroom and at home. As the computer downsized from its mainframe origins to a version that was small enough to sit on a desk, it became a machine that soon had applications in education. In the mid-1980's, Apple Computer became the first technology company to aggressively market itself as a valuable conduit to education in the classroom, establishing business relationships with many schools by providing desktop computers through its Apple Classrooms of Tomorrow campaign. Later, different handheld devices found their way into education. Initially, the college setting was the predominant site of these instruments but, over time, the K-12 classrooms were the more likely location to find such educational tools. A significant reason for their early popularity might have been financial, as the handhelds were as little as one-tenth the cost of a regular computer (Joyner, 2003). An early study of note was to explore the introduction of PalmPilots into a middle school science classroom. It was found that the students showed a preference for the PalmPilot over a textbook when engaged in their reading assignments (Blue, 2006).

With the advent of the computer, the teacher's role has begun to evolve from the dispenser of information to one of being a facilitator in guiding the student in a personal quest to discover useful knowledge (Owen, Farsaii, Knezek, & Christensen, 2005; Niles, 2007). Many studies point to higher test scores after the introduction of personal computers in the classroom, along with increased teacher motivation and satisfaction (Lowther, Ross, & Morrison, 2003; Shieh, 2012; Norris, Hassain, & Soloway, 2013).

Other investigators, however, would dispute these outcomes, having observed no significant change in test scores (Fullan, 2011; Hansen, 2012).

Computers, in whatever form, can engender a degree of excitement and intrigue, especially amongst young children and adolescents. Along with that intrigue can come the inherent student motivation to use that technology as a learning device (Jacobs, 2012). However, it would be a mistake to assume that all schoolchildren are experienced and savvy in dealing with the digital world (Bennett, Matton, & Kervin, 2008; Jacobs, 2012). Beyond not being able to completely operate a computer with all of its varied functions, school aged children also struggle with the interpretation of material that is either presented to them or found online. Despite a student's possible excitement with the introduction to learning with the help of the internet, for example, they can exhibit a true lack of information literacy, being unable to adequately evaluate sources and their validity (Wang, Ke, Jin, & Hsu, 2012).

Educators can also face significant challenges with computers in the classroom, both perceived and real. For a number of teachers, the traditional methods of presenting subject material to the student that had become routine, be it paper and pencil or writing on the board in front of the class, are at odds with the trajectory of delivery that technology has produced. Different programs have been developed to assist the teacher with the integration of technology in the classroom, with the result being positive teacher perception of technology and better integration (Koch, Heo, & Kush, 2012; Mundy, Kupczynski, & Kee, undated). Beyond simply becoming acclimated in the utilization of technology, the teacher still provides an invaluable human resource. Student access to more information does not necessarily make us better citizens, nor does the application of

more technology bring meaning or understanding to an issue. This must somehow be part of the pedagogical role of the teacher (Smits, 2001). Another potential challenge is the student becoming distracted by a plethora of competing media that is readily available to the user, such as social media, text messages, email, games, or browsing the internet (Bugeja, 2007; Wood, Zivcakova, Gentile, et al, 2012). Some educators, however, feel that challenge is counterbalanced by the potential benefits of having the advancement of technology in the classroom and, further, that creative and innovative teachers can utilize technology to help reform and refine their teaching practices (Fang, 2009; Kay & Lauricella, 2011).

Despite these challenges and others, the presence of technology in the classroom has created many opportunities for the educator. The ability to quickly and conveniently assess for student learning, such as clicker technology, is one example. With a clicker device in hand, the student can respond to the teacher's question in a multiple choice format with the push of a button. As opposed to one or two students voicing an answer to an inquiry during a lecture or discussion, all of the students can respond, providing immediate universal assessment (Keough, 2012). If such technology is applied in this way, the students' answers could also be instantaneously graded, a welcome assist in alleviating a teacher's workload. In another example, teachers routinely observe that their classroom of students will absorb and master subject material at different rates, creating a potentially significant challenge to individual learning. Technology can help with differentiated instruction, according to Keck and Finney (2005). With differentiated instruction, a framework is established to provide students of diverse academic abilities a means to master subject content so each student in a classroom can learn effectively

(Tomlinson, 1999). In trying to get all students to contribute to a class despite differing abilities, technology can present the same general material to the students at different levels of difficulty. The individual student computer can also present the same material in different formats, such as audio, video, or written, to best match the needs of the learner (Keck & Finney, 2005). Some investigators conclude that, despite an ambitious goal of anticipating differences in student abilities, differentiated instruction is very difficult in practice, as their case study met with limited success (Ruys, Defruyt, Rots, & Aelterman, 2013). In her general review of the literature, however, Hall (2002) found an ample number of successes in differentiated instruction. As there is an increasing amount of resources available to present similar material in differing formats and styles, it would seem reasonable to believe the dilemma of differentiated instruction is more solvable than ever in the classroom.

METHODOLOGY

As it was a school-wide goal to utilize the Apple iPad at least to some degree in every classroom, this research studied the implementation of the computing device from the vantage point of the student, parent, and teacher. A variety of methods of data collection were undertaken with my College Preparatory Biology classes consisting of high school sophomores and juniors. The intent was to study the students' individual response to the introduction of the iPad in their biology class and also attempt to compare summative test scores of the classes with the iPad this school year to last year's traditional classroom setting. The Beginning of the School Year Survey was given to explore the students' opinions and self-assessments in regard to pre-existing knowledge of the iPad, personal organizational strategies, note taking habits, and preferred reading

methods (Appendix A). Where responses could be tabulated quantitatively, the data was averaged; written student opinions that were illustrative of a more collective group response were included when reporting that particular point of view. Mid-Term Student Surveys (Appendix B & C) were given during the middle of the fall and spring semesters. These surveys employ a Likert Scale, with a range of responses to the statements as follows: 1- *Strongly Agree*, 2- *Agree*, 3- *Undecided*, 4- *Disagree*, 5- *Strongly Disagree*. The students were asked their opinions about reading from the new text book format (iBook) and preferences for completing and turning in school work as well as preparing for a new test now that they had an iPad at their disposal. Also, for the first time, possible student distractions, such as game playing and messaging on their iPad during class sessions were investigated in this round of surveys. An End of the Year Student Survey (Appendix D) was administered to explore the students' opinions about the role of the iPad resulting in any possible changes in their study habits over the course of the school year. Beginning with the Mid-Term Student Surveys and continuing with the End of the Year Student Survey, new questions were added in the attempt to assess student motivation for learning, in general, with the iPad, as well as their perception of possibly more successful personal learning in science, specifically because of the assistance of their iPad this school year. For the last three student surveys, the individual Likert Scale scores were averaged for the group.

The Parental Survey for the 1:1 Classroom was issued at the beginning of the fall semester for the 2013-2014 school year to solicit initial parent attitudes (Appendix E). This survey attempted to glean personal parental thoughts about how their child, having continual access to an iPad, might impact possible success in school moving forward into

the new year, along with expectations of their child's teachers in this new classroom environment. Also, a baseline was sought in measuring parental experience and comfort with computers and the iPad itself. As with the students' initial survey, quantitative data was averaged for the group and enlightening individual parental responses were included wherever possible to illustrate a particular point of view. A second survey, entitled Parental Survey for the 1:1 Classroom, End of Fall Semester (Appendix F) was also administered, along with a Parental Survey for the 1:1 Classroom, Looking Back (Appendix G) at the end of the 2013-2014 school year to monitor the parents' opinions throughout this initial year of student iPad use. These two surveys were made up of identical statements in which the parent rated the statements with a Likert Scale grading system as previously listed earlier in this section. Here, the intent was to investigate any possible trends in parent assessment of their child's first year in the one-to-one classroom as they considered their engagement in school studies, possible distractions they might have observed, and perceived organizational level with the new computing device at their constant disposal.

A Student Interview (Appendix H) was undertaken with a cross section of students of varying academic abilities, based upon their entrance examination test score along with my evaluation of a student's progress in our biology class. The interview sought to acquire extended, candid comments from the students about how they navigated their school day with the consistent, continual availability of the iPad in class. Also, as the students are exposed to many different teaching styles and classroom environments throughout their school career and this last year, in particular, it was an opportunity to solicit suggestions as to improving our biology class in ways that were not

previously thought of or we were even aware of before. Journal entries were also made by this instructor about the one-to-one classroom, reflecting upon perceived successes and failures of the process (Appendix I). This entailed observations of the classroom environment, my perception of student engagement, self-assessment of effectiveness in lesson presentation, and reflections on my personal feelings about fulfillment or lack thereof at various times of the school year in different classroom and administrative situations. Also, a Science Department Teacher Survey on the 1:1 Classroom was administered to investigate individual instructor opinions of the first school year with the iPad in their classroom (Appendix J). So as to assure complete anonymity, a series of statements were utilized with the teachers responding only in a Likert Scale scoring method as previously noted earlier in this section. The survey investigated the teachers' thoughts on their transition to the new classroom environment, student engagement and productivity, success in integrating the device into their curriculum, administrative support, and potential in differentiating instruction. In each survey that employed the Likert Scale in toto (Appendices B, C, D, F, G, & J), the scores regarding each question were averaged for the group (student, parent, or teacher) and reported.

Finally, in the attempt to relate summative test results of this school year and last (a traditional class setting), similar unit tests (Scientific Method, Biochemistry, Cellular Anatomy & Energy, Cell Growth & Division, and Ecology) were compared, based upon the relative quartile of the students' entrance test score when applying for admission to the school. This was done in cooperation with the school's guidance department and with the approval of our school administration. To ensure individual anonymity with this section of research, quartile grouping only was utilized in trying to investigate the test

score trends. The scores of all five unit tests were averaged for each quartile group and reported.

The data sources provided a triangulation matrix to help answer research questions (Table 1).

Table 1
Data Triangulation Matrix

Research Questions	Data Source 1	Data Source 2	Data Source 3
What are my students pre-existing opinions and self-assessments?	The Beginning of the School Year Student Survey	Student Surveys: Fall Mid-Term Spring Mid-Term End of Year	Student Interviews
What are the parents' views on the implementation?	Parental Survey for the 1:1 Classroom	Parental Survey for the 1:1 Classroom, End of Fall Semester	Parental Survey for the 1:1 Classroom, Looking Back
What will be the students' performance with the one-to-one classroom?	Summative Test Scores in Comparison to Entrance Test Scores		
What will be my response to the one-to-one classroom?	Personal Journal	Teacher Observation of Students	
What will be the response of the teachers in the science department to the one-to-one classroom?	Science Department Teacher Survey on the 1:1 Classroom		

The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained.

DATA AND ANALYSIS

Data to assess the implementation of the iPad in our biology classroom was collected from the perspective of the students, parents, and science department teachers. The first four surveys were completed by the students. The Beginning of the School Year Student Survey (Appendix A) found that 76% of the College Preparatory Biology students had previously used an Apple iPad prior to the start of the fall semester, 2013, while 24% had not ($N= 51$). Beyond having any exposure to the device, 42% of the students surveyed felt they were *very familiar* with the iPad, 56% categorized themselves as *somewhat familiar*, while 2% said they were *not very familiar* (Figure 1).

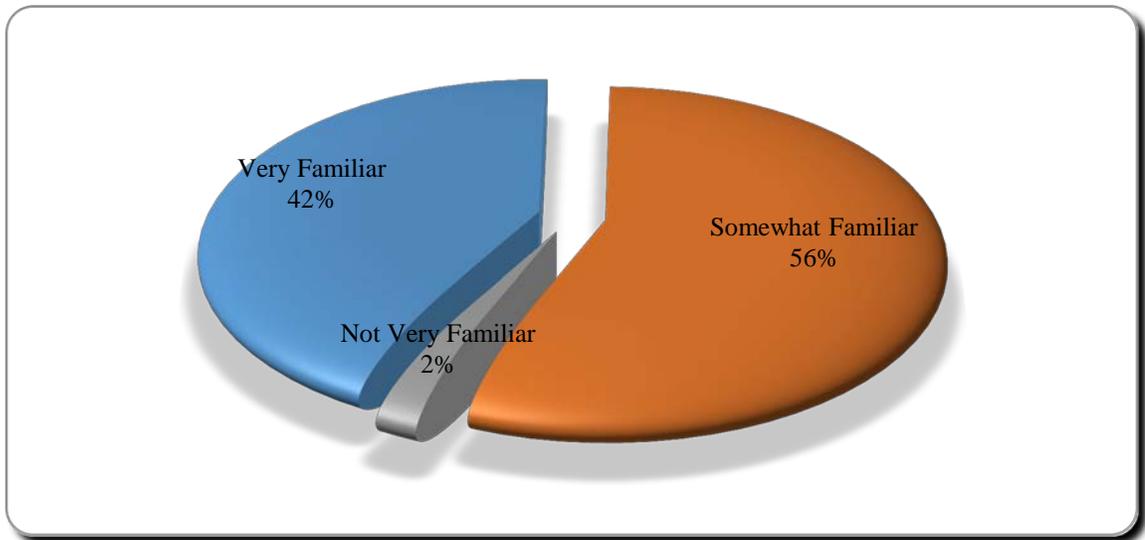


Figure 1. Student Familiarity with the Apple iPad, Start of the School Year, ($N= 51$).

A second question investigated the students' self-assessment of their reliance upon notes taken during class sections. The responses were organized into categories as *relying a lot on my notes*, *relying somewhat*, and *do not rely much at all*. Forty percent

felt they relied a lot on their notes, 50% somewhat, while ten percent answered they did not rely on their notes much at all.

The students were also asked to assess their degree of organization with school papers such as assignments, notes, and class worksheets. Fifty percent described themselves as *very organized*. Included in those responses were follow up comments such as, “Yes, because I’m a neat freak,” and, “Yes, I do consider myself organized because if something is out of place, I have to do something to fix it.” Twenty-six percent classified themselves as *somewhat organized*. A student from that category commented, “(I am) kind of organized, as sometimes I get a little overwhelmed.” Another student described himself as somewhat organized because, “Throughout the year, I get less and less organized.” Eighteen percent of the students felt they were *not at all organized*, with one student saying, “It’s something I need to improve.” (Figure 2)

The final question in The Beginning of the School Year Student Survey looked at student preference of reading media. When asked their choice, 43% preferred reading from a book, 31% chose a computer, and 26% responded that either medium was acceptable. When asked which method of reading, book or computer, led to better retention, 53% of the students chose reading from a book, 37% preferred reading off a computer screen, eight percent felt there was no difference in retention, while two percent were not sure which medium was better for them (Figure 3).

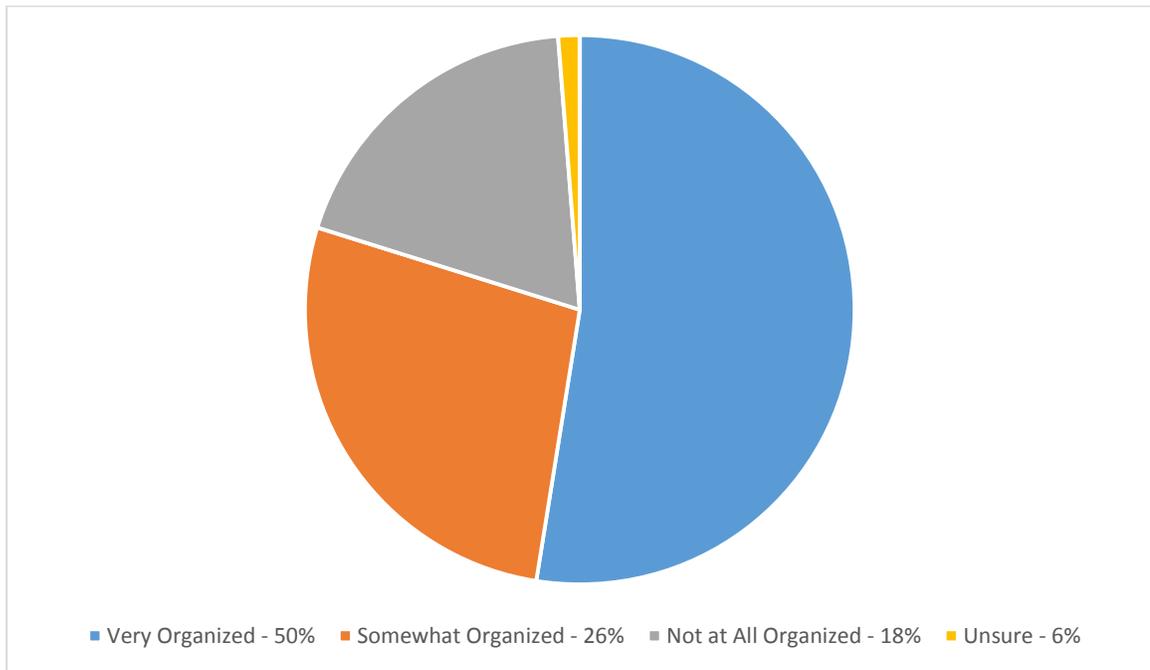


Figure 2. Percentage of Student Response to the Question: Do you consider yourself organized, (N= 51).

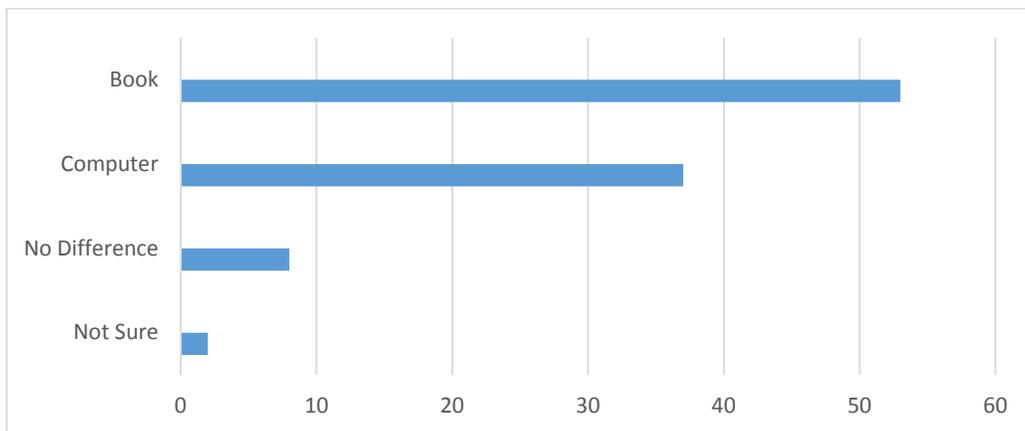


Figure 3. Percentage of Students' Preferred Reading Medium, Book or Computer, (N= 51).

As to some of the reasons why they preferred a book, one student responded, “So far, a book is better, because it is easier to write notes in them along with highlighting key terms.” Another student also choosing a book wrote, “I prefer a book because it is right in front of me on paper.” Still another stated, “A book, because I like actually holding the text.” Among those who preferred the computer, one student responded, “I like to read from the computer because of the interactivity.” Another who chose the computer summed up his choice thusly, “I like the computer more because books put me to sleep.”

The first follow-up survey, The Fall Mid-Term Student Survey (Appendix B), asked the students to rate their degree of confidence to succeed in a science class, in the attempt to try and gauge the comfort level in which the students entered this course. Twenty-three percent replied they felt *very confident*, 74% felt *somewhat confident*, while only three percent answered they were *not confident at all* (Figure 4).

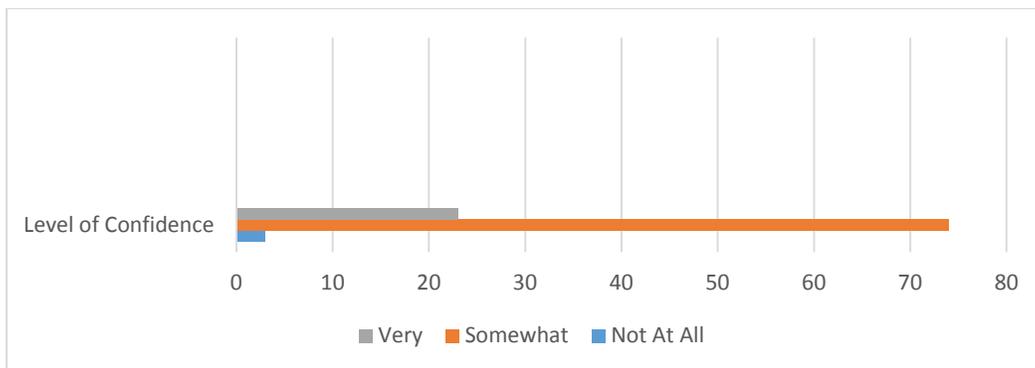


Figure 4. Percentage of Student Response to the Question: Thinking back to the start of the school year, how confident were you in your ability to succeed in a science class, (N=51).

Beyond this initial question, the three successive surveys over the course of the school year investigated possible trends in the students’ opinions about the integration of the

iPad into their daily academic routine, with five core questions looking to investigate possible trends (Appendices B, C, & D). When responding to the statement that it was easier to complete my homework with the iPad, 40% of the students either *agreed* or *strongly agreed* with the Fall Mid-Term Student Survey, rising to 55% with the Spring Mid-Term Student Survey, and again to 78% with the End of the Year Student Survey (Figure 5). One student commented, “It was a challenge at first, but over time it became easier to figure out.” Another student appreciated the ease of organization, saying, “Everything is with you all the time. I did not have to worry if I left it in my locker.” Also finding it easier was a student who stated, “I liked it because it had all my stuff together. It keeps me organized.”

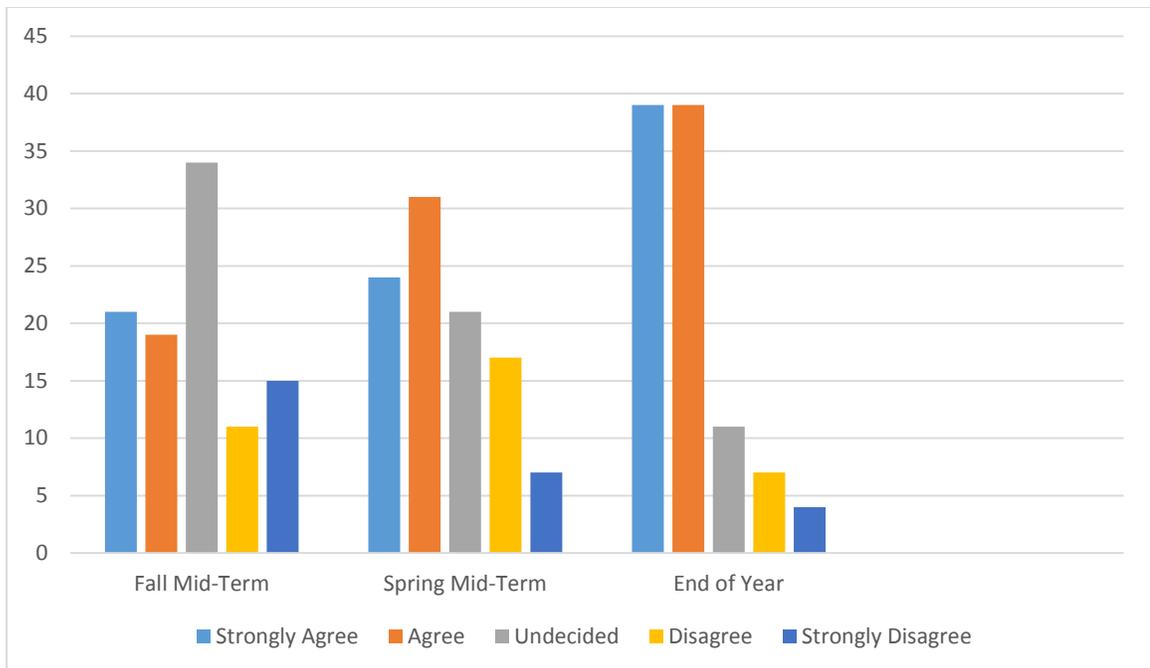


Figure 5. Percentage of Student Response to the Survey Statement: *It is easier to complete my homework with the iPad*, (N= 47).

A second question investigated student reading preference between a regular textbook and the iPad. Here, the results were a little more mixed as they certainly preferred the iPad, but a notable percentage were still undecided even at the end of the year. With the spring and end of year surveys, 54% expressed a preference for the iPad over the textbook. One of those students stated, “It was kind of easier to find things in the book and so I felt more organized with my reading.” Another positive response was, “I liked the iBook because it was easier to highlight and it was interactive.” At year end, 33% remained undecided as to their preference (Figure 6). As one student expressed his doubts, “I was worried that it would be a big distraction. I thought it would be better to have it at home as a luxury, because I didn’t think it would really fit in for me.”

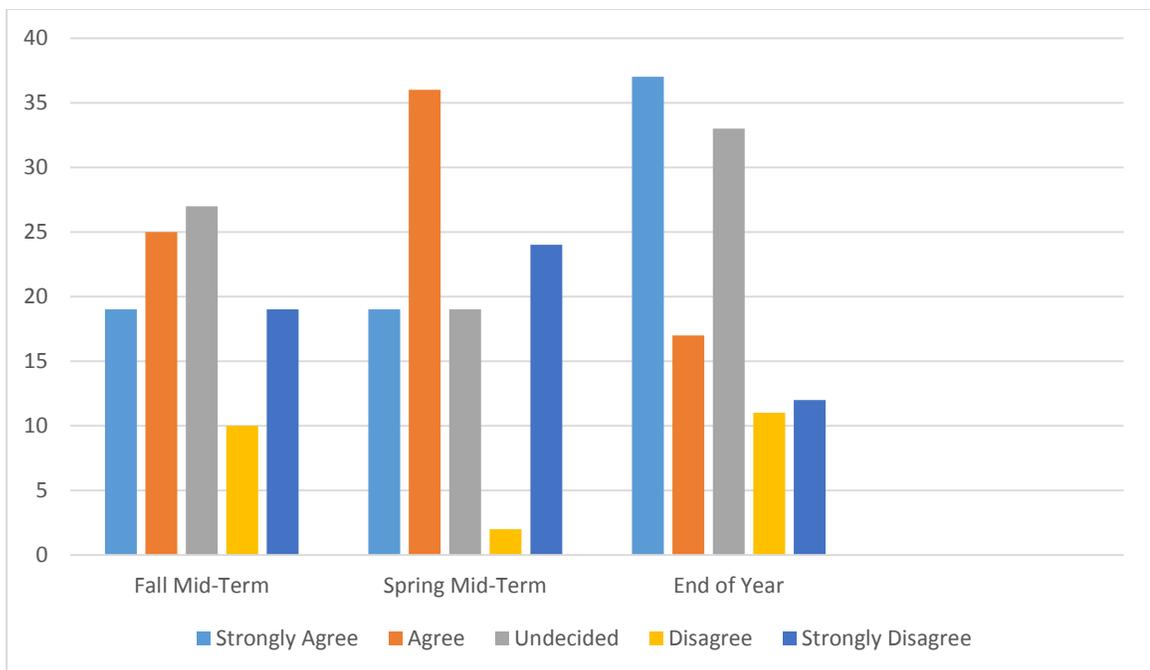


Figure 6. Percentage of Student Response to the Survey Statement: *I enjoy reading from the iBook over a regular textbook*, (N= 47).

A third question looked at the possibility of the iPad facilitating quiz and test preparation for the students. When comparing the fall mid-term to the end of the year, the students seemed to trend toward the opinion that the iPad helped them with preparation as 28% in the fall did not agree that it was easier to prepare, while only 14% felt that way by the end of the school year (Figure 7). Indicative of the students who welcomed the iPad for test preparation were those who valued the support they felt with organization. “I preferred to put my notes in the iPad,” one student said, “it was just easier to go back to them.” A dissenting view seemed to be that writing out the notes was the better method. “I never go back and look at Notability (application),” said one student, “Writing down my notes helped me remember them more. By just typing, it never seems to really sink in.”

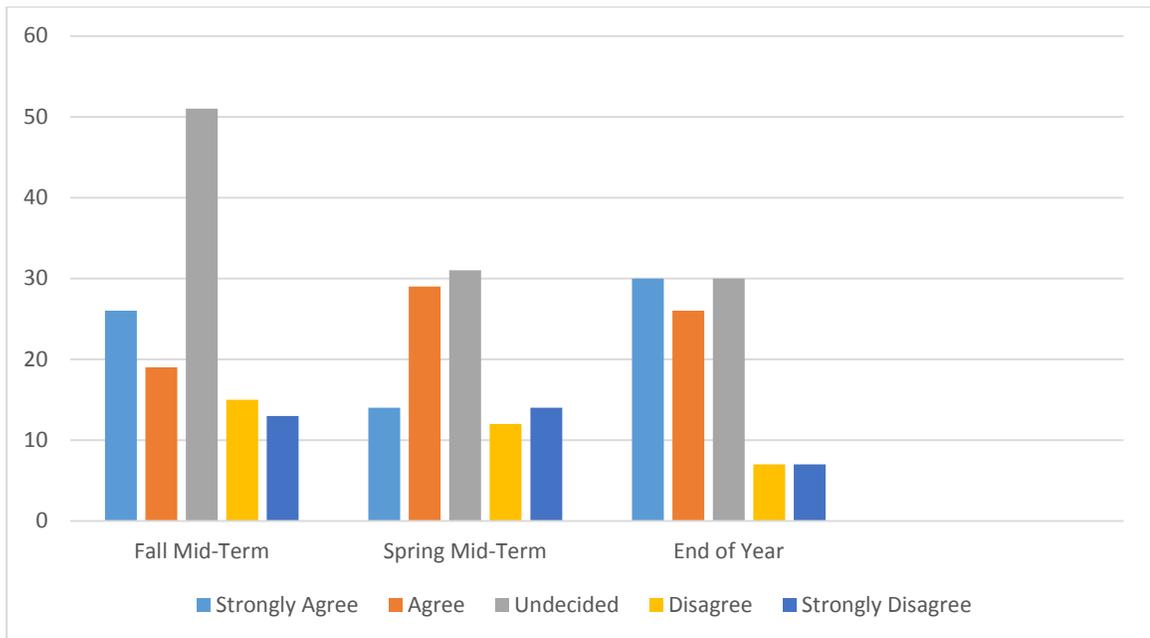


Figure 7. Percentage of Student Survey Response to the Question: Preparing for quizzes and tests is easier than last year because I have an iPad this year, (N= 47).

A fourth question investigated the possibility that the iPad would stimulate the student to go a little further on some topic that our biology class had studied. Here, the

results are inconclusive. In the fall survey, 29% either *strongly agreed or agreed* with the statement that they would look up information because they were already on the computer, rising to 59% in the spring, and then going back down to only 38% in the end of the year survey (Figure 8). One student comment of note is, “I like that we had access to the internet 24/7, which was useful and that we could share documents and information.”

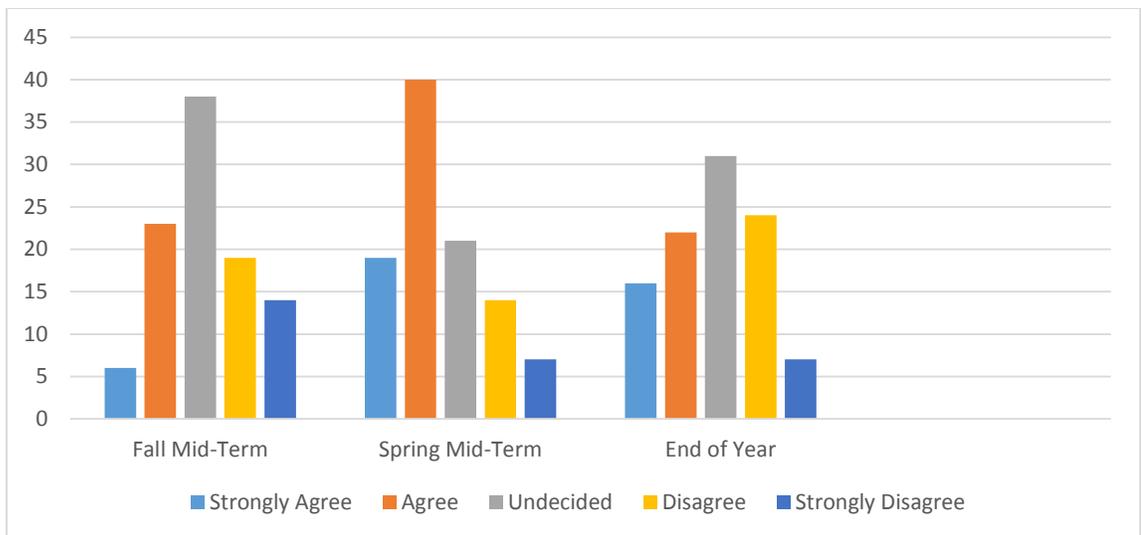


Figure 8. Percentage of Student Response to the Survey Statement: I have found I am more curious about topics in my classes, including biology, and I am more motivated to look things up on my own time due to greater access to information, (N= 47).

The last core question in the student surveys looked at possible distractions because the iPad was always with the student in the classroom. This topic was approached in varying ways in our surveys. The students were asked directly in the Spring Mid-Term Survey to respond to the question of distraction due to the iPad (Appendix C). Forty-seven percent of the students either *strongly agreed* or *agreed* that the iPad caused them to be distracted, 21% were undecided, while the remaining 31% did

not feel it was a distraction (Figure 9). “The iPad could make it more difficult to learn in class,” said one student, “because I would lose focus, playing a game, reading a book, or googling some random topic.” Another expressed empathy for his teacher by saying, “Yes, it made it harder at times. The teachers were more frustrated when kids were on games and things like that.” With the Fall Mid-Term and End of the Year Surveys, the students were asked to estimate the frequency at which they either played games on their iPad or sent text messages while in class (Appendices B & D). Fifty-nine percent in the fall and 56% at the end of the year thought they had played games at least daily when in class (Figure 10), while 75% in the fall and 68% at the end of the year reported sending some number of text messages during class. Roughly one third of the students thought they sent ten or more text messages a day during class time (Figure 11). One student summed up his thoughts this way, “Every once in a while, you kind of get sidetracked with games or with friends. I don’t always really like it but it just happens.”

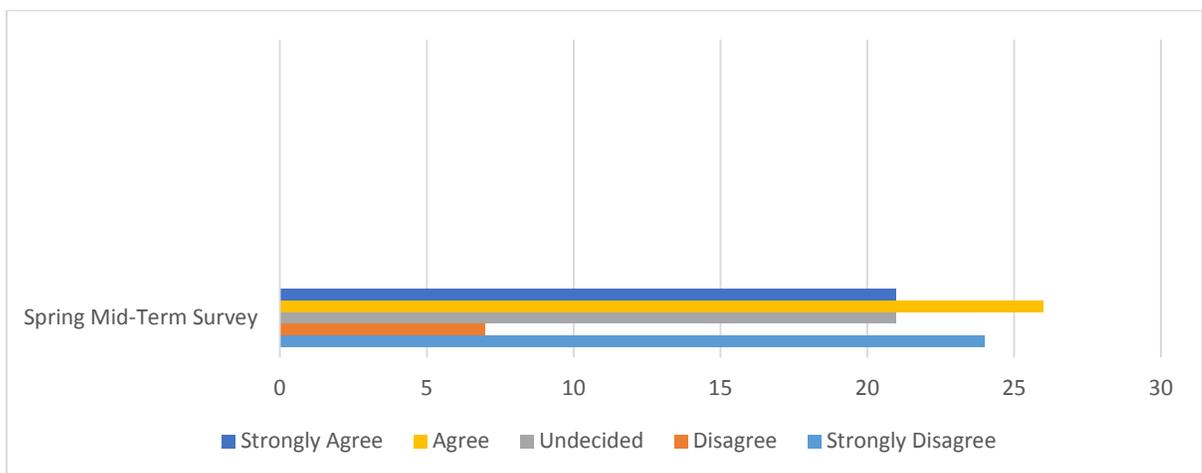


Figure 9. Percentage of Student Response to the Statement: It is easier to get distracted this year from what is actually going on in class because I have an iPad, (N= 47).

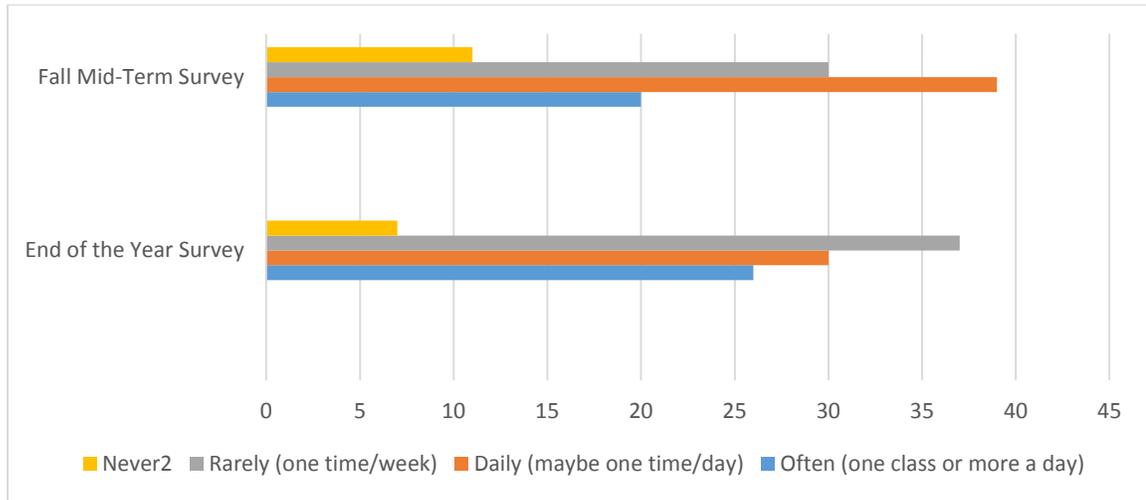


Figure 10. Percentage of Student Response to the Question: How often do you play games on your iPad during the school day, (N= 47).

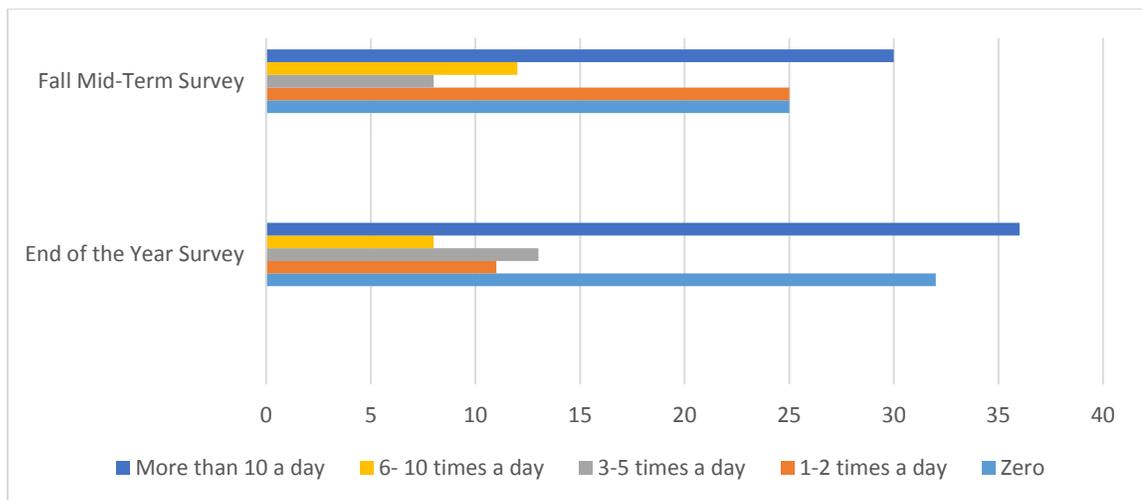


Figure 11. Percentage of Student Response to the Question: How many messages do you send/receive from other classmates a day, (N= 47).

The final student question to report investigated the students' opinion as to learning effectiveness and the iPad. As part of the Fall Mid-Term Student Survey, the question asked was simply, do you feel that the iPad helped you learn more effectively at school this semester? Fifty-six percent of the students answered yes, 38% said no, with

six percent unsure (Appendix B). For the spring and end of the year surveys, the student was asked to rate their response to the statement, I think I have learned more about science this year because I have an iPad, according to the established Likert Scale. In the Spring Mid-Term Student Survey, 51% either *strongly agreed or agreed*, with 34% responding *undecided*, while 15% either *disagreed or strongly disagreed*. Similarly in the End of the Year Student Survey, the statement was rated at 52% *strongly agree or agree*, 35% *undecided*, and 13% *disagree or strongly disagree* (Figure 12). From a student that might be categorized as an undecided (the surveys were anonymous), “It seems to depend upon how the individual student learns best. Some things are just better to write down on your own. Also, I prefer more hands on kind of labs.” Another student shared her sentiments this way, “With more hands on labs, there is just less distractions.”

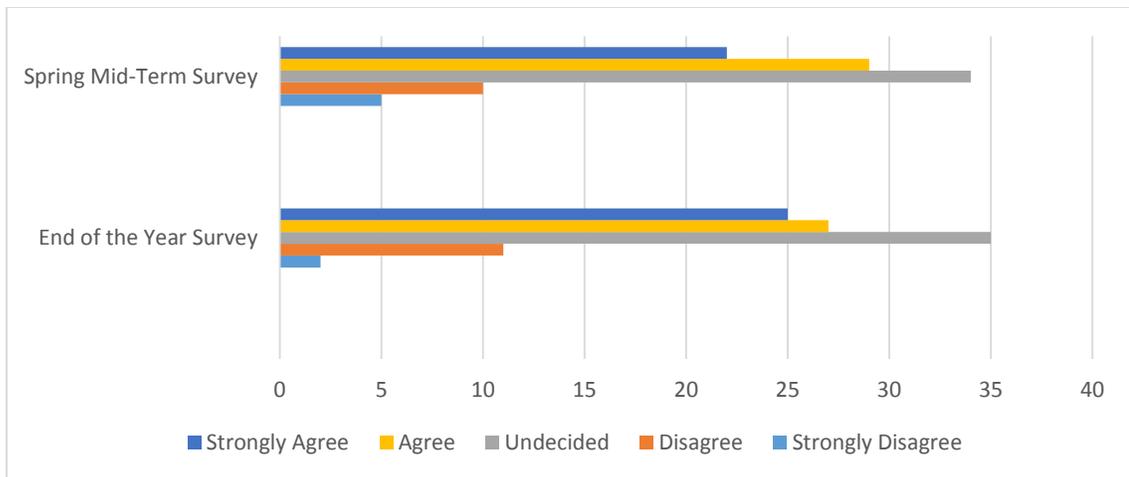


Figure 12. Percentage of Student Response to the Statement: *I feel I learned more about science because I have an iPad*, (N= 47).

The parents of the students in my biology classes were also given surveys to take at the beginning of the school year and at the conclusion of the fall and spring semesters (Appendices E, F & G). In the Parental Survey for the 1:1 Classroom at the start of the

year, 83% responded that, yes, they thought their child would be more excited about school armed with an iPad, with 10% saying no, and seven percent being unsure ($N= 29$). Fifty-two percent of the parents believed their child would learn more effectively with the iPad, seven percent responded no, while 41% were not sure. Ninety percent of the parents surveyed reported being personally comfortable with the routine use of a computer with 10% responded they were unsure. Seventy-nine percent of the parents who responded to this survey reported they could navigate an iPad, 14% said no, and seven percent were unsure (Figure 13). A fifth question that solicited comments was asked of parental expectations of the teachers now that there are student iPads in the classroom. Indicative of those parents who expected the teacher to have a high level of expertise with the device was the comment, “I expect the teachers to be fully knowledgeable and familiar with the iPad so if a student is having some sort of problem with theirs (sic), the teacher will be fully capable of troubleshooting.” Following that same theme, another wrote, “(That) the teachers become comfortable and use the iPad as much as the students are expected to.” Other parents wrote of their concerns that their children would begin to go in a direction they did not want to see occurring. “Not to be ‘plugged in’ all the time,” wrote a parent, “Please use the iPads as a resource, not as the teacher.” Another had a similar sentiment, writing, “I don’t want CB (Christian Brothers High School) to lose their personal contact with the students and parents due to technology.” Other parents were worried about the iPad becoming a distraction to their child in the classroom, with a representative example of this concern being, “They better monitor my kid at all times.”

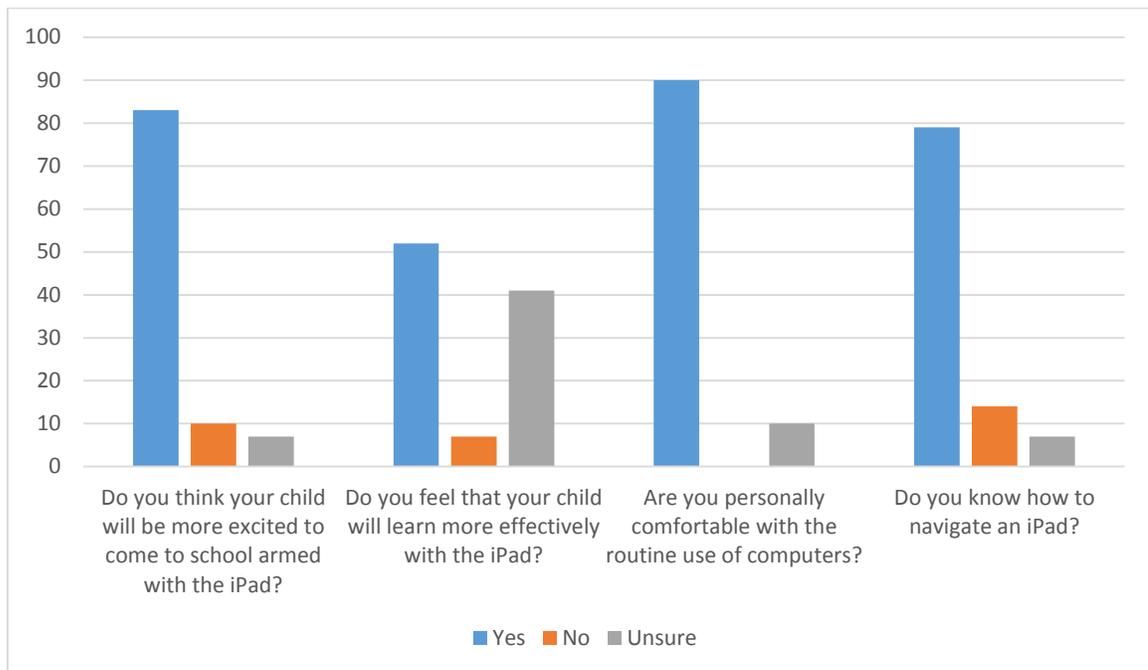


Figure 13. Percentage of Parent Response to Questions: Parental Survey for the 1:1 Classroom, (N= 29).

The Parental Survey for the 1:1 Classroom, End of the Fall Semester utilized the Likert Scale to investigate opinion and perspective of their child (Appendix F). The parents responding to the survey were fairly evenly divided as to the initial favorability of the individual iPad being in the classroom, with 39% either *strongly agreeing* or *agreeing*, with 33% *disagreeing* or *strongly disagreeing*, while 28% were *undecided* (Figure 14). Thirty-nine percent also felt their child was more engaged at school because of the iPad, 33% percent being undecided, while 28% did not agree. Similarly in number, 33% of the parents felt the iPad created a distraction for their child when at school, with 11% being undecided, while 56% did not see the device to be a problem in that manner. When asked if the student iPad experience was positive to date, 56% of the parents felt it was, 11% were undecided, and 33% did not believe that to be the case. Finally, a question was asked about the parental observation of their child being possibly more organized because of the iPad. One-

half of the parents felt it helped their child become more organized, with 23% undecided, and 27% did not observe that having taken place (Figure 15).

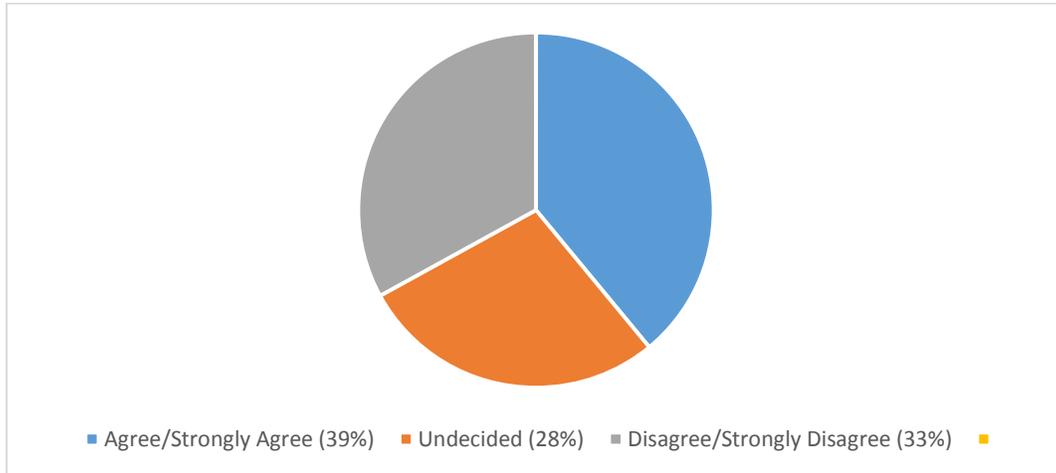


Figure 14. Parental Response to the Statement: At the start of the school year, I was in favor of the daily iPad use for the students at Christian Brothers, (N= 19).

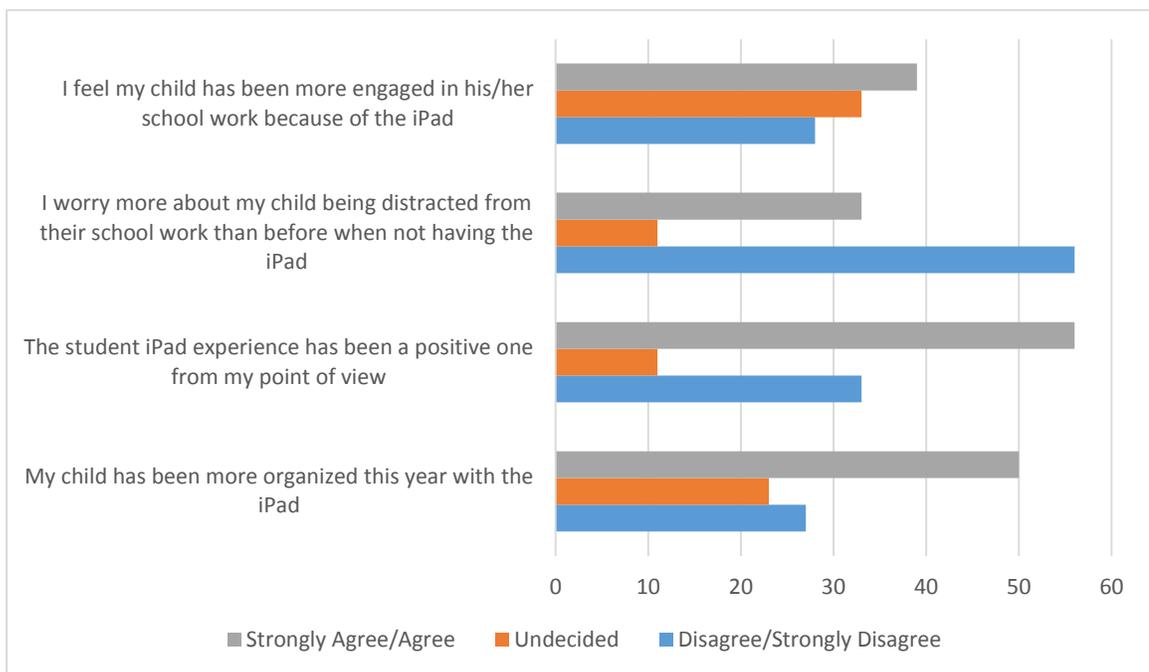


Figure 15. Percentage of Parent Response to Survey Questions: Parental Survey for the 1:1 classroom, End of the Fall Semester, (N= 19).

A final follow-up survey had been planned, the Parental Survey for the 1:1 Classroom, Looking Back, but the survey results were not deemed reliable due to a lack of a representative sample size so it was not reported upon here (Appendix G).

The last survey undertaken was that of teachers in our department. The survey results for the Science Department Teacher Survey on the 1:1 Classroom were divided into four general categories: teacher overview of the program, personal and professional fulfillment, classroom challenges, and perceptions about the possible enhancement of student learning (Appendix J). Starting with teacher overview of the program, 50% of the science teachers felt it had been a successful transition to the iPad this school year, with 20% disagreeing with that statement, while 30% were undecided ($N= 10$). Only 20% of the science faculty thought it was time for the iPad to be implemented in the classroom, although 70% believed the Information Technology (IT) Department had prepared them well for this very event by the start of the school year. When questioned as to whether they will utilize the device more in the next school year than they did this last year, 40% of the teachers responded that they would, 50% did not think so, with 10% undecided (Figure 16).

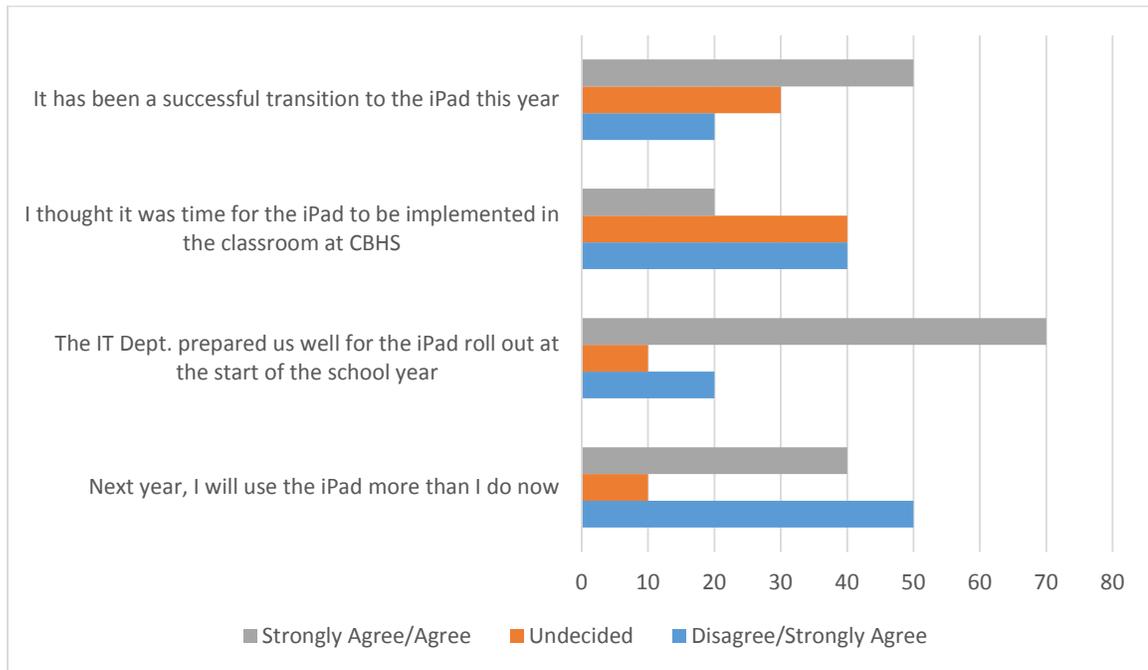


Figure 16. Percentage Teacher Response to Questions Regarding Teacher Overview of the Program: Science Department Teacher Survey on the 1:1 Classroom, (N= 10).

The next grouping of questions looked at teacher personal gratification and professional fulfillment, with 30% reporting an enjoyable transition to the iPad, 40% undecided, and the remaining 30% not viewing the implementation in a positive way. Also, 66% of the science faculty *disagreed* or *strongly disagreed* with the statement they had felt more fulfillment as a teacher because of the addition of the iPad to their classroom. Only 30% of the teachers believed they were well prepared for the implementation of the iPad in the classroom, although 70% felt the IT Department had prepared them well, as previously reported (Figure 17).

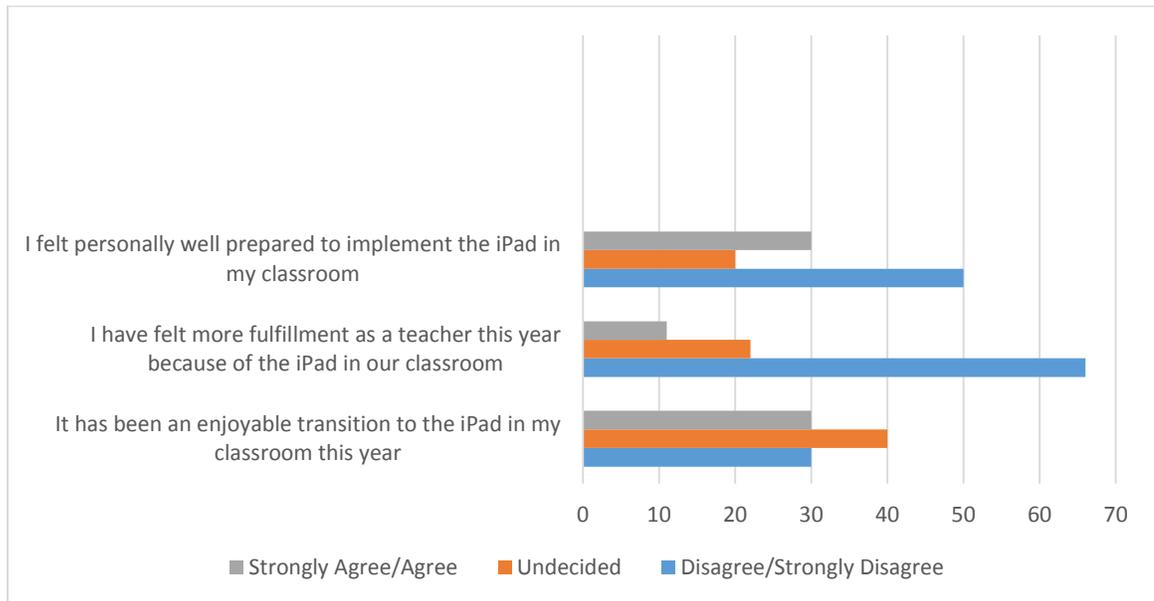


Figure 17. Percentage Teacher Response to Questions Regarding Personal and Professional Fulfillment: Science Department Teacher Survey on the 1:1 Classroom, (N= 10).

A third group of questions investigated teacher challenges with the one-to-one classroom. Forty percent of the teachers felt their frustration level to be higher this last school year and 60% thought that the students were wasting time on nonproductive activities such as game playing and messaging during class. Sixty percent of the science faculty were of the opinion that they were personally not prepared to implement the iPad and instead should have waited one more year before launching the program (Figure 18).

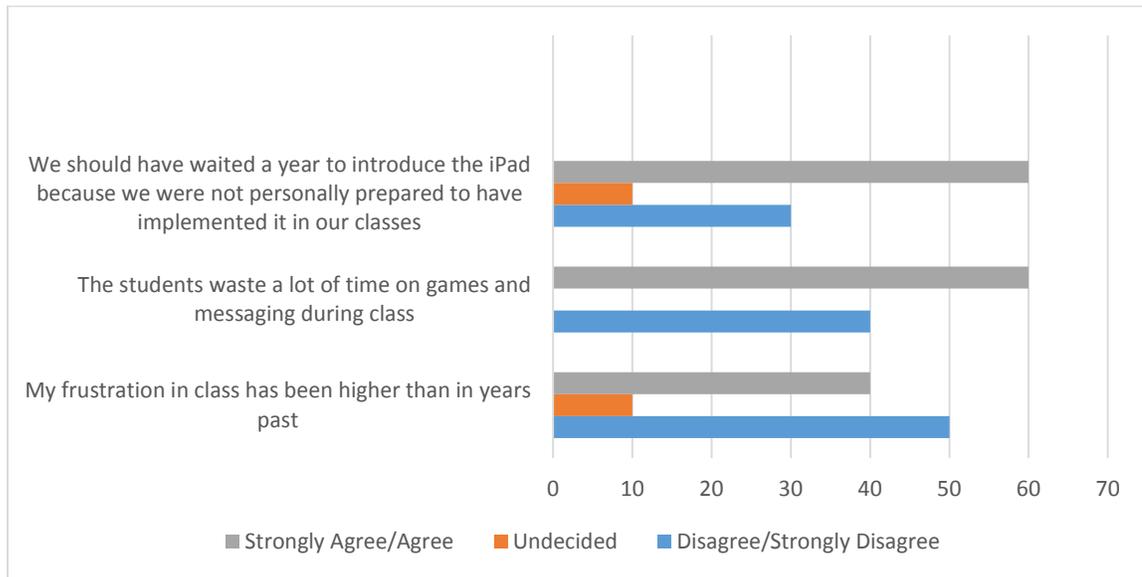


Figure 18. Percentage Teacher Response to Questions Regarding Challenges in the Classroom: Science Department Teacher Survey on the 1:1 Classroom, (N= 10).

Enhancement of student learning was the fourth theme of teacher survey questions. Only 20% of the science teachers believed the students learned more effectively with the iPad, with 30% undecided, and 50% not believing this to be true. However, 50% noted that their students were more engaged this year compared to the previous year. Regarding differentiated instruction, 50% of the science faculty believed the iPad will assist them in this modality to accommodate various student learning styles. Finally, 40% of the teachers think the iPad is an important device in student preparation for college, with 30% undecided, and 30% in disagreement with this statement (Figure 19).

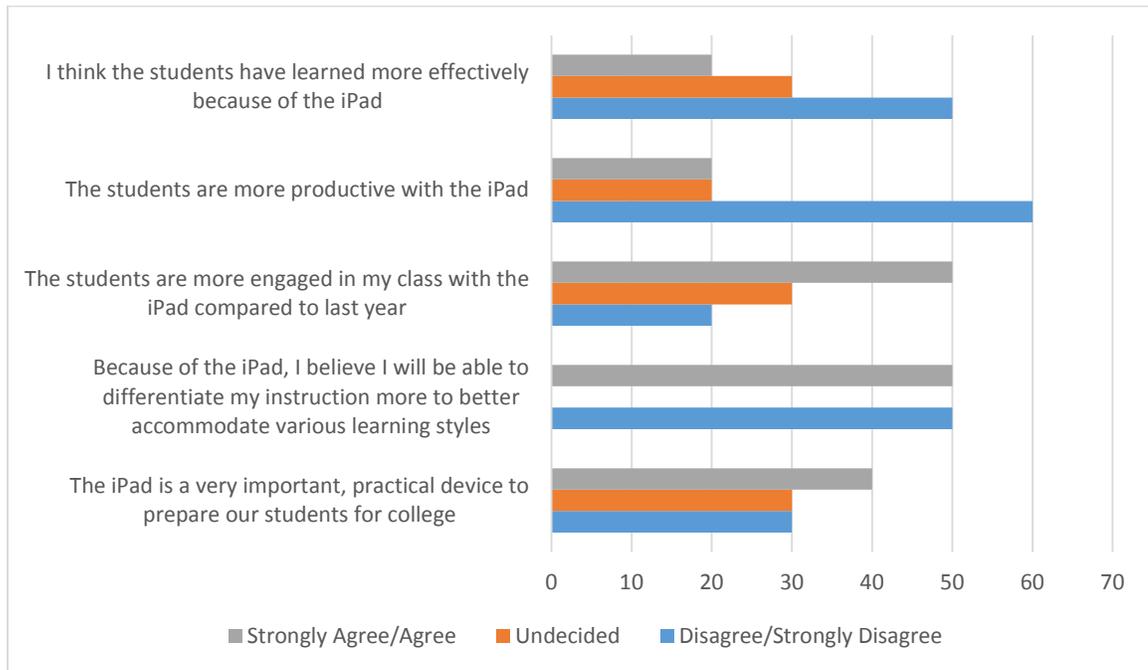


Figure 19. Percentage Teacher Response to Questions Regarding Enhancement of Student Learning: Science Department Teacher Survey on the 1:1 Classroom, (N= 10).

In comparing the biology unit test scores of the students grouped by quartiles (based upon their high school entrance scores), no real trend could be elicited between this last year's one-to-one classroom students and their immediate predecessors. The two middle level quartile students from the one-to-one classes scored higher on their tests, while the highest and lowest quartiles from the previous school year scored higher (Figure 20).

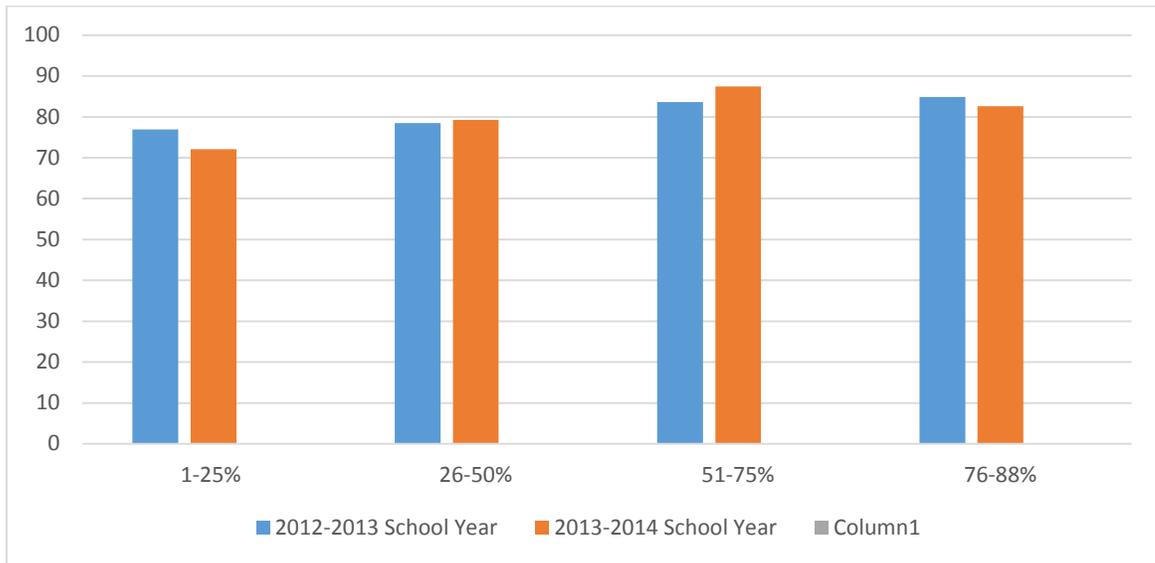


Figure 20. Average Percentage Unit Test Scores, Grouped by Student Entrance Examination Quartile, 2012-2013 and 2013-2014 Biology Classes.

INTERPRETATION AND CONCLUSION

The data from the surveys taken at the start of the school year would suggest that the pieces were in place for a successful transition to the Apple iPad in our biology classroom. The parents overwhelmingly believed their children were more excited about school because of the addition of the device. Both the students and their parents reported feeling comfortable and familiar with the iPad at the beginning of the school year. The science teachers responded positively when looking back on the degree of support and preparation that was offered by the IT Department, although they themselves did not necessarily feel well prepared. Now, possibly that is a reflection of recalling their trepidation in starting the school year with the expectation to incorporate this new, somewhat unfamiliar technology with a classroom full of high school students.

As the school year progressed, one trend that did develop was the students increasingly found it easier to complete their homework and prepare for tests with the

iPad. Student interviews pointed to an ease in organization and consolidation of access to their course material. Presumably, this positive student response to the device could lead to increased engagement in the course. In turn, this might lead to better student learning in our classroom (DuBois, 2011; Grodner & Rupp, 2013). The data from the student surveys also revealed a change in student reading preferences as the iBook became the preferred medium over a textbook. In relating the surveys and interviews, the students seemed to enjoy the interactive capabilities of the iBook for our class. This would suggest the possibility that the students would come to view their iPad as a device that could help them succeed in school.

One behavior that rose initially in the first semester of the implementation was that of the student being stimulated to independently explore interesting topics that arose from our biology course material. That is, they would come across some topic that would stimulate their curiosity, which would lead to personal research on the part of the student simply because the iPad is already there in front of them in class. However, as the year progressed, the students reported less interest in engaging in such behavior. This may tie into a decidedly negative outcome of the omnipresent device, that being the distraction of game playing and text messaging on the iPad. Teachers cited this as a significant problem in their survey, as did the parents. Additionally, the students themselves later acknowledged this to be a definite daily challenge. There is little doubt this was a school-wide problem in our first year with the one-to-one classroom. It is possible that not only did it take away from the students spending adequate time on required class assignments but it also may have taken the students' thoughts away from personal exploration of

science topics that were of interest to them. This is a topic that deserves attention in any review of my one-to-one classroom moving forward.

Another area of my research that should be taken in context would be that of comparing summative test results from the one-to-one classroom this last year and its traditional predecessor. While the averages do give me some data to look at, a more valid comparison to assess progress can be made next year as our science department switched to a different textbook this school year along with the addition of the iPad. Nevertheless, my exposure to the student entrance test scores and discovering the relative quartiles did assist me in the attempt to address the significantly wide range of student academic abilities in my biology classes.

VALUE

Looking back on our foray into the one-to-one classroom, the program, while not without its challenges, was a most worthwhile undertaking. Further, its value was certainly augmented by this action research as I was often required to systematically view the program from different perspectives- the student, parent, and science teacher. Between surveys and interviews, I was able to frequently gain access to the student viewpoint about our classroom. The surveys were helpful in that it gave me an opportunity to investigate opinion trends on homework, test preparation, and organization. The student interviews, while anecdotal, were significantly helpful in gaining their perspective, especially so in that I often try to evaluate the relevance of assignments, class discussions, lab sessions, and tests via the estimation of how a teenager might see our class. It may take on different formats from year to year, but carving out time during the school year for interviews is well worth it in terms of student

feedback. Many comments made during the course of the interviews might have been a little off topic but, nonetheless, offered a wonderful access to unfiltered opinions about our class and the relationships formed, especially student to teacher. One comment consistently made that was most instructive to me, especially in light of our introduction of a new technology, was that it was patently obvious the students valued the human touch of their teachers above all other attributes. Technology can be a wonderful addition to our classroom, and it was, but the students continually said they look to their teachers for guidance in their studies. Personally, that means it is important always to try and form solid relationships with the individual student, even if technology may somehow alter or challenge those relationships.

With the introduction of the iPad this year came the downloaded textbook, termed an iBook. One way in which I tried to guide the students in our biology course was to put together a reading notes system. A sample is included in the appendices (Appendix K). The goal of these notes is to assist the students with their reading assignments, with sequential questions so as to get them to process the different topics I wanted the students to work through as they perused the iBook. These supplemental notes led the students to place great value on their reading, and it became a study pathway they came to believe was crucial to their success in the class. Because of this, the students dove more deeply into the subject matter, the result being that the combination of the interactive textbook and note system allowed me to put the class on a good pace all the while ensuring the students were adequately exposed to our fundamental course material. And, it gave me an excellent way to measure an individual student's progress at will. Moving forward, given the success of this practice, I will develop the reading notes further with extended topical

study so those students who exhibit the need for a faster or more rigorous pace can be more consistently challenged.

Often, when the virtues of the one-to-one classroom are put forth, the advantages of a so-called “flipped classroom” are included, whereby the students learn new subject content by watching video lectures at home and then work on their homework assignments in class under the direction of the teacher. At least for the student that is in my classroom (college preparatory but not accelerated), they are almost universally averse to any such assignment where they are required to view lectures at home, whether mine or by somebody else. So, what was done instead was to assign short (five to ten minutes, at most) video presentations in class where the students had a series of questions to answer. During these sessions, I circulated throughout the classroom to be available for questions and, frankly, to also make sure all students stayed on task. Examples this year included homeostasis, stages of mitosis, and vestigial structures. Incidentally, in deference to the student interview preferences, paper worksheets were provided this year, although I would predict that in coming years the preference may soon be to complete such assignments online.

About five to six weeks into the one-to-one introduction of the Apple iPad this school year, game playing began to take place. As the year went on, a reasonable estimate would be that 20-25% of the students engaged in this behavior, ranging from once a week in our class to a daily habit. The immediate effect of game playing, of course, was to take the students’ focus from the class activities, be it discussion or an individual assignment, requiring either a quiet individual redirection or stopping the class entirely and respectfully scolding a wayward game player. From discussion with other teachers, this

was a school-wide problem. Also, it is my belief that the administration had not expected this to become such an issue; they are in the process of developing guidelines to respond to this unwanted behavior. Personally, I will put strict rules in place to begin the next school year, including after school detention for repeat offenders. However, I do believe that if the student has completed their assignment and asks permission, quiet outside activities, including game playing will likely be something I will permit during the last five minutes of a class session. This may seem counter to logic, and I may change my mind here, but a few minutes at the end of a session of strong work by the student does not seem unreasonable.

One of the joys of teaching science is that the students, maybe more than any other discipline, are able to leave their desk, go to the lab bench, and explore, create, build, and test different ideas with their hands. Such an exercise, while not completely unique to science, is nonetheless an expected and anticipated part of the high school experience. My goal and challenge is to make sure the hands on experience remains a viable part of our biology laboratory while sequentially introducing different technologies and instrumentation into our labs. This will take time and frequent professional development, but a good mix of technology and traditional activities such as dissection and botanical labs, for example, will definitely augment the student experience.

Finally, a question to be asked is how I might have changed as a teacher due to this new program. In reviewing the school year with our newly developed one-to-one classroom, I began to get better, more proficient, with technology. Just having a year to constantly use the device made me get better. Also, the reception that the students exhibited to the downloaded iBook allowed me to explore ways to develop my own

reading notes system. In effect, it became a major part of our curriculum. Further, as I continued to refine the system and shared it with colleagues in our department, it was a learning tool that was widely utilized by the teachers and, anecdotally, was well received by students across different classes and academic levels. This was a somewhat serendipitous outcome but I will move to continue to develop this system. I firmly believe the students in my classroom learned the course content better and in a more focused way because of their diligence with the reading notes system. Another thing I tried was clicker technology, with the help of a colleague in a different department. I still need to get better and faster with it, but it is conceivable that with practice it will be something more commonplace in my classroom giving me another tool in student assessment and feedback on my practices.

There is little doubt that the one-to-one classroom is here to stay at Christian Brothers High School. It is no longer a novelty nor a cause for consternation. Instead, it is a part of our charge as faculty to get better at managing and expanding the program with each passing year. In truth, it is a welcome and exciting challenge. Maybe the biggest hurdle to getting better in this environment is to find the proper balance between being the so-called “expert” in technology, to paraphrase some parents, yet remember there is a teenager sitting in front of that device with a real need for guidance in my biology class. I look forward to trying to get better in such an environment next year.

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APPENDICES

APPENDIX A

THE BEGINNING OF THE SCHOOL YEAR STUDENT SURVEY

Student iPad Survey- Fall, 2013

- 1) Have you ever used an iPad before this year? Y / N
- 2) How would you categorize your familiarity with the iPad? (Please circle one)
Very Familiar Somewhat Familiar Not Very Familiar
- 3) What kind of note taker are you?
- 4) How much do you depend upon your notes? When do you refer to them?
- 5) Do you consider yourself organized? Why/Why not?
- 6) Do you have a hard time keeping all of your school papers together? Y / N
- 7) What would help you become more organized?
- 8) Do you prefer to read from a book or off a computer screen? (please circle one)
- 9) Which method of reading (book or computer) leads you to better remember what you have read? Why?
- 10) Is there anything else you can think of to add? (Please list your comments on the back of this paper)

APPENDIX B
FALL MID-TERM STUDENT SURVEY

APPENDIX C

SPRING SEMESTER MID-TERM STUDENT SURVEY

Spring Semester Mid-Term Student Survey

Please consider the following statements and rate them as follows:

- 1- Strongly Agree
- 2- Agree
- 3- Undecided
- 4- Disagree
- 5- Strongly Disagree

It is easier to complete my homework with the iPad	1	2	3	4	5
I enjoy reading from the iBook over a regular text book	1	2	3	4	5
Turning in my school work to the teacher is easier than last year	1	2	3	4	5
Preparing for quizzes and tests is easier than last year because I have an iPad this year	1	2	3	4	5
I have found that I am more curious about science and therefore research random related topics on my own time	1	2	3	4	5
I feel I have learned more about science because I have an iPad	1	2	3	4	5
Because I have an iPad, I am more motivated to learn	1	2	3	4	5

APPENDIX D
END OF THE YEAR STUDENT SURVEY

End of Year Student Survey

Please consider the following statements about the iPad and your school work and rate them as follows:

- 1-Strongly Agree
- 2- Agree
- 3- Undecided
- 4- Disagree
- 5-Strongly Disagree

It is easier to complete my homework with the iPad	1	2	3	4	5
I enjoy reading from the iBook over a regular text book	1	2	3	4	5
Turning in my school work to the teacher is easier than last year	1	2	3	4	5
Preparing for quizzes and tests is easier than last year because I have an iPad this year	1	2	3	4	5
I have found that I am more curious about science and therefore research random related topics on my own time	1	2	3	4	5
I feel I learned more about science because I have an iPad	1	2	3	4	5
Because of the iPad, I am more motivated to learn	1	2	3	4	5

How often do you play games on your iPad during the school day? (please circle one)

Never Rarely (1x per week) Daily (1x per day) Often (1 class or more a day)

How many messages do you send/receive from other classmates a day? (please circle one)

Zero 1-2 3-5 6-10 More than 10

APPENDIX E

PARENTAL SURVEY FOR THE 1:1 CLASSROOM

Parental Survey for the 1:1 Classroom

Parents, thank you for taking the time to respond to these questions. The intent of these questions is to simply understand you/your family's views so as to better educate your child on a daily basis.

1) Do you think your child will be more excited about school armed with an iPad?

Why/Why not?

2) Do you feel that your child will learn more effectively with the iPad?

Why/Why not?

3) Are you personally comfortable with the routine use of computers?

4) Do you know how to navigate an iPad?

5) What will be your expectations of the teachers now that there is an iPad to be used in the classroom?

APPENDIX F

PARENTAL SURVEY FOR THE 1:1 CLASSROOM, END OF FALL SEMESTER

Parental Survey for the 1:1 Classroom, End of the Fall Semester Survey

Parents, thank you for taking the time to respond to these questions. As you look back and reflect on the first semester, your child has had the iPad at school every day. Please rate the following statements according to the scale listed below.

- 1-Strongly Agree
- 2-Agree
- 3-Undecided
- 4-Disagree
- 5-Strongly Disagree

At the start of the school year, I was in favor of the daily iPad use for the students at Christian Brothers High School	1	2	3	4	5
I feel my child has been more engaged in his/her school work because of the iPad	1	2	3	4	5
I worry more about my child being distracted from their school work than before when not having the iPad	1	2	3	4	5
The student iPad experience has been a positive one from my point of view	1	2	3	4	5
My child has been more organized this year because of the iPad	1	2	3	4	5

APPENDIX G

PARENTAL SURVEY FOR THE 1:1 CLASSROOM, LOOKING BACK

Parental Survey for the 1:1 Classroom, Looking Back

Parents, thank you for taking the time to respond to these questions. As you look back over the 2013-2014 school year and reflect on your thoughts about this first year with the student iPads, please rate the following statements according to the scale below.

1-Strongly Agree

2-Agree

3-Undecided

4-Disagree

5-Strongly Disagree

At the start of the school year, I was in favor of the iPad for the students	1	2	3	4	5
I feel my child has been more engaged in his/her school work because of the iPad	1	2	3	4	5
I worry more about my child being distracted from their school work than before when not having the iPad	1	2	3	4	5
The student iPad experience has been a positive one from my point of view	1	2	3	4	5
My child has been more organized this year because of the iPad	1	2	3	4	5

APPENDIX H
STUDENT INTERVIEW QUESTIONS

Student Interview Questions

- 1) What did you think of having an iPad, your own personal computer, with you in every class this year?
- 2) Did you feel that with the technology changes this year, you had a different kind of relationship with your teachers? Did it affect your personal relationships with other students at school?
- 3) Did you prefer working individually with your iPad in biology class for reading, notes, and videos, or did you prefer more lab sessions working with your partners? Why?
- 4) Think, for a moment, about the lab notebook you kept in our class. After having a year's worth of experience with the iPad, do you think you will learn about science more by writing things down in a notebook or would it be better to use the iPad as a virtual notebook? Why?
- 5) If you were assigned to help teach the biology class next year, would you emphasize, a) more use of the iPad for things like listening to class lectures, videos on different topics, and virtual labs, or b) do you think your students will learn more by doing hands on labs, paper worksheets, and having the teacher only lecture during class time?
- 6) Was there anything (or more than one thing) that you really liked about having the iPad in our biology class this year compared to past science classes you took?
- 7) Thinking about possible challenges in our class, were there any ways the iPad made things more difficult, not easier for you to learn?
- 8) Are there any comments or ideas you would like to share?

APPENDIX I
JOURNAL ENTRY PROMPTS

Journal Entry Prompts

1. Successes
2. Frustrations/Failures
3. Areas Needed for Improvement
4. One Thing I Learned About the iPad This Week

APPENDIX J

SCIENCE DEPARTMENT TEACHER SURVEY ON THE 1:1 CLASSROOM

Science Department Teacher Survey on the 1:1 Classroom

Thank you for taking the time to respond to this survey about observations you might have about our transition to the 1:1 classroom. Please consider the following statements and rate them according to the scale below:

- 1-Strongly Agree
- 2-Agree
- 3-Undecided
- 4-Disagree
- 5-Strongly Disagree

- | | | | | | |
|--|---|---|---|---|---|
| 1) It has been an enjoyable transition to the iPad in my classroom this year | 1 | 2 | 3 | 4 | 5 |
| 2) It has been a successful transition to the iPad | 1 | 2 | 3 | 4 | 5 |
| 3) I thought it was time for the iPad to be implemented in the classroom at CBHS | 1 | 2 | 3 | 4 | 5 |
| 4) I think the students have learned more effectively with the iPad | 1 | 2 | 3 | 4 | 5 |
| 5) The students are more productive with the iPad than not | 1 | 2 | 3 | 4 | 5 |
| 6) The students are more engaged in my classes with the iPad compared to last year | 1 | 2 | 3 | 4 | 5 |
| 7) My frustration in the classroom has been higher than in years past | 1 | 2 | 3 | 4 | 5 |
| 8) The students waste a lot of time on games and messaging during class | 1 | 2 | 3 | 4 | 5 |
| 9) I feel personally well prepared to implement the iPad in my classes this school year | 1 | 2 | 3 | 4 | 5 |
| 10) The IT Department prepared us well for the iPad roll out at the start of the school year | 1 | 2 | 3 | 4 | 5 |
| 11) The subject I teach can be covered more efficiently with the | 1 | 2 | 3 | 4 | 5 |

iPad over traditional methods of delivery

- | | | | | | |
|--|---|---|---|---|---|
| 12) I often have the students use the iPads in laboratory sessions | 1 | 2 | 3 | 4 | 5 |
| 13) I have felt more fulfillment as a teacher because of the iPad in our classroom | 1 | 2 | 3 | 4 | 5 |
| 14) Because of the iPad, I believe I will be able to differentiate my instruction more to better accommodate various student learning styles | 1 | 2 | 3 | 4 | 5 |
| 15) I have really tried to find new ways to implement the iPad in my classes wherever possible | 1 | 2 | 3 | 4 | 5 |
| 16) Next year, I will use the iPad more than I do now | 1 | 2 | 3 | 4 | 5 |
| 17) Based upon my observations, the students learn more by doing hands on labs versus virtual labs | 1 | 2 | 3 | 4 | 5 |
| 18) The iPad is a very important, practical device to prepare our students for college | 1 | 2 | 3 | 4 | 5 |
| 19) We should have waited a year to introduce the iPad because we were not personally prepared to have implemented it in our classes | 1 | 2 | 3 | 4 | 5 |
| 20) The iPad seems more effective for the students' individual use over a personal laptop computer | 1 | 2 | 3 | 4 | 5 |

APPENDIX K
STUDENT READING NOTES SAMPLE

Chapter 12 DNA

Name _____

12.1 Identifying the Substance of Genes (page 576)

All living things (organisms) are based upon a universal genetic code. All organisms store the information they need to live, grow, and reproduce in a genetic code written in a molecule called DNA (Deoxyribonucleic acid). That information is copied and passed from parent to offspring. With a few small differences, life's genetic code is almost the same in every living thing on earth. DNA is a nucleic acid; along with proteins, carbohydrates, and lipids, nucleic acids compose the major macromolecules essential for all known forms of life.

In chapter 10, we studied the concept of cell division. During that study, we saw that before a cell was going to divide, it first made a complete copy of its genetic information. That information is bundled into packages of DNA known as chromosomes. Chromosomes are threadlike structures of DNA and protein that are found in the nucleus of a cell. In chapter 11, we looked at genetics (the study of heredity). In this chapter, we will explore the connection between information and heredity. That is, what is the structure of DNA, and how does it function in genetic inheritance? To answer that question, we will look at 1) how scientists determined that DNA is responsible for storing, copying, and transmitting genetic information, 2) the discovery of the basic structure of DNA, and 3) how cells copy their DNA.

(p.577) To understand genetics, scientists first realized they first _____

If the molecule that carries genetic information could be identified, then _____

****This, then, is the story of the discovery of the central role of DNA in heredity****

First, go through figure 1.1 (p.577) with your partner and answer the following questions...

Which bacteria is the disease causing strain? _____ Which is the harmless strain? _____

The S strain looked smooth when examining their appearance under a microscope, hence the name. The R strain looked rough, so it was the "rough" or R strain.

What was Griffith's initial hypothesis? _____

When the S strain bacteria was killed (made non-deadly) by the heat and injected into the mice, what happened? _____

When Griffith mixed the heat killed bacteria (from the S strain) and the harmless bacteria (R strain) and injected that mixture into the mice, what happened? _____

Upon examination of the mice's lungs, what did Griffith observe? _____

So, if the S strain, which was the deadly strain until it was supposedly killed by the heat, still was capable of killing the mice, what did Griffith conclude as to how that could happen?

Define transformation _____

In his experiment with lab mice (1928), Frederick Griffith transferred the deadly component of a strain of pneumonia bacteria to a non-deadly strain, and, therefore, determined that there must be a genetic “transforming factor” in the bacteria. While the heat had killed the disease causing capability in the first generation of the bacteria, after cell division, the offspring bacteria had inherited that disease causing capability. Griffith thought that transforming factor was a gene.

Oswald Avery and his lab team (1944) repeated Griffith’s experiment and then looked at the factors from a chemical perspective. He looked for the “transforming factor” that Griffith first identified as a gene in 1928. Avery’s team extracted (removed) various types of macromolecules from the heat killed bacteria.

What macromolecules did they remove? _____, _____, _____,

Did transformation still occur? _____ So, were any of them the transforming factor? ____

What was then isolated and extracted from the heat killed bacteria and, this time, transformation did not occur? _____

What did Avery’s team conclude? _____

(p.581) –what is the role of DNA in heredity?

What was the critical assumption that scientists made as they moved forward in their study of DNA? _____

What is the foremost role of DNA? _____

What do genes control? _____

Before a cell divides, what must happen? _____

What had Mendel’s work shown about genes? _____

