

ELECTRONIC NOTEBOOKS TO DOCUMENT THE ENGINEERING DESIGN PROCESS: FROM PLATFORM TO IMPACT

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Abstract

As technologies develop, the tools used in classrooms to support student learning are ever evolving. While this change can provide avenues for new exploration and enhanced educational experiences, critically assessing these developments is essential to ensure that there are added educational benefits to these new technologies and tools. This paper details an electronic notebook that was implemented in select sections of a first-year engineering course to replace the use of traditional paper notebooks. While the implementation seemed successful and there were anticipated benefits to switching from a paper to electronic based system, critical assessment data based on good assessment practices was collected to truly measure the impact of the change and new technology use. In this paper, we report on the electronic notebooks themselves and the assessment results.

Introduction

Effectively using technology in the classroom has been a concern in education for many years [1, 2]. While there are a variety of technologies that are used to support education (e.g., computers [3], clickers [4], cell phones [5], etc.), we have chosen to focus our work on electronic notebooks (i.e., website development for project documentation). We not only explain and explore the use of this technology in our courses, we assess its impacts comparing sections without the new technology to sections with the implementation.

There is a body of work in education that evaluates and discusses the impacts of electronic portfolios (EPs) which in many ways are similar to electronic notebooks. EPs are digital

collections of artifacts that provide authentic, valid, and reliable evidence of a learning experience [6]. While all EPs are a collection of artifacts, their purposes vary. Some are used to assist a learning process, others to showcase students' work, and others to assess that work [7]. Our electronic notebook implementation was used for all three purposes. We wanted a platform for our students with the following characteristics:

- (1) Students could document their process
- (2) Instructors could use the electronic notebooks to assess the overall project
- (3) Students could make a final product that could be shared with others

Specifically in engineering education, electronic notebooks have been used in a variety of capacities. We highlight three implementations below comparing them to our project. First, Puccinelli and Nimunkar [8] used electronic notebooks in a biomedical engineering design program for sophomore through senior level students. Their results demonstrated that both faculty and students enjoyed the electronic platform for its anytime access and ability to be accessed in the future. We hoped that through our implementation we would also see benefits related to access and availability. The platform chosen for this project allowed students to access the electronic notebooks in the course, but it also has the capability for long term access which is described later in this paper.

Cardenas [9] also reported on the use of electronic laboratory notebooks. For her work, students used the electronic notebooks in a sophomore level course with multiple experiments. Electronic and paper notebooks were compared and no large differences were

found between implementations; however, she suggests that further investigation is needed to explore electronic notebooks compatibility with other tools and whether or not it improves student technical writing. For our implementation, students were using tools (e.g., SolidWorks, Excel, C/C++ coding platforms, etc.) that were difficult to transition to a paper notebook. We hoped that the electronic platform would make this connection between tools more feasible. Below we provide examples of ways the electronic notebook interfaced with products students developed from other tools. Additionally, by using electronic notebooks students were also able to capitalize on collaborative software tools like Google Docs. These types of tools were used before with the paper notebooks, but in the electronic environment, we hoped students would use them more actively and directly link them to their notebooks further using their potential.

Finally, Kudrle and Iyer [10] used electronic notebooks for research purposes. Their goal was to investigate an implementation of electronic notebooks to improve data sharing and distributed analysis. Through adjustments to their spreadsheet platform, they were able to support that data sharing and distributed analysis can be improved, but they are still working on this investigation to make it more viable for research. While our project did not involve typical research data, we were interested in implementing a platform that had the ability for group collaboration and teamwork. This was possible with the paper notebooks, but we believed the electronic platform would allow for this collaboration more easily.

While the contexts of the examples above are different than our context, they help support the initial implementation of the electronic notebooks. They also highlight the possible enhancements to the educational experience that can be gained from the use of electronic notebooks. To further understand our implementation, details of the program, course, and project for which this work relates have been provided in the following section.

It should be noted that there were also potential drawbacks to the electronic notebooks that were considered. For example, students may be less organized in an online environment than a physical paper based one. Additionally, students would have to learn a new tool to even use the electronic notebooks that they before did not have to master. This meant that the time it took for students to integrate information from their design project to their notebooks would increase. Despite the potential challenges, we believe the benefits outweighed the drawbacks and proceeded with the implementation and assessment.

Background

The Fundamentals of Engineering for Honors (FEH) program [11] at The Ohio State University (OSU) is a two course sequence. The purpose of the sequence is to expose students to the engineering design process while teaching them fundamentals related to problem solving, communication, teamwork, ethics, etc. The first course in the sequence focuses on problem solving using tools such as Excel, MATLAB, and C/C++. Additionally, students participate in different labs each week, each of which highlights a different discipline of engineering giving students a place to work in a hands-on environment. Following the labs, students complete abstracts, lab memos, or lab reports on the content of the labs in order to enhance their technical writing skills. Some of these assignments are done individually to give students an opportunity to learn fundamental technical communication skills, while others are completed as a group so students begin developing their teamwork abilities. The second course in the sequence gives the students a design project to complete, which strengthens their principles of teamwork, problem solving, communication, and time management. Both courses in FEH are facilitated by an instructor and a team of teaching assistants (TAs), who are available to help the students in class, in lab, and during open lab sessions. The course employs a flipped classroom model to encourage active learning [12].

As mentioned above, students participate in a design project their second term. One of the projects is to build an autonomous robot which is the context for this work [13]. The students have approximately ten weeks to build and code this robot so that it may complete a given set of tasks on a competition track which is unique each year. In order to give students a realistic experience, the design project has limited time and resources. Also students are required to keep a notebook to track the development of their robot. Traditionally, this notebook was kept in paper form in a very large binder that students brought with them to class when they worked on the project. This notebook contained an archive of the entire robot design experience from early brainstorming to final competition results. Typically the notebooks included technical drawings of custom robot parts, 3D renderings of the entire robot, budgets, schedules, and robot testing logs.

During the Spring 2014 semester, in an effort to enhance the use of technology in the classroom and reduce the number of pages printed for the notebooks, a selection of FEH course sections had students keep track of their progress by using an electronic notebook rather than a physical paper one of the past. At the same time, the university sponsored and maintained tool u.osu.edu was released. This platform enables students to create their own personal websites and blogs using the Word Press framework. Additionally, the platform allowed for group project sites to be built that were secured under the university system. This tool was ideal to be used as the platform for the new electronic notebooks in FEH. Students were able to access and edit their notebook at any time of day or night and could upload various forms of media to their website (videos, photos, Twitter feeds, etc.) that used to be a challenge to include in the paper version of the notebooks. In addition, instructors had unlimited access to the websites for grading, feedback, and evaluation purposes which was not possible when the notebooks existed in a physical form. Another factor influencing the use of the new platform was that all students on the project

team would have access to the portfolio during their entire college career and after they graduate. This would allow them to showcase their robot in interviews with potential employers. These many factors were integral in enhancing the student experience and supported the adoption of the new platform in select sections.

The alternative implementations to the electronic notebook in the u.osu.edu platform included already existing collaborative software, such as Dropbox and Google Docs. Both options have presentation challenges and often require the use of an in depth filing system to achieve strong organization. However, the u.osu.edu platform would allow students to use existing collaborative software in conjunction with website platform allowing them to capitalize on the strengths of multiple systems. Additionally, it was impossible to include the interactive elements of the electronic notebook into Google Docs such as videos and 3D models that could be easily integrated into the u.osu.edu platform. Considering these items, using u.osu.edu was not only a convenient choice but provided the most benefit to transitioning the notebooks to electronic form.

Anticipated Benefits of the Electronic Notebooks

As discussed above, there were many logistical elements that made the use of the electronic notebooks a viable option; however, we also saw additional potential benefits that we felt could enhance the notebooks as both a place to showcase the robot project and serve as a form of assessment for the course. The instructional team hoped that the new electronic journals would better the overall experience of an FEH participant making the notebook more relevant and useful to their learning. Some features that initially made the electronic notebook a better option than the paper notebook included enhanced navigability and accessibility, clearer technical drawings, and better multimedia capabilities. These items are

discussed below along with example photos from students' electronic notebooks.

With this new platform, there was no longer any need for students to decide which member of the team was to take care of the notebook, and physical damage or loss of this key assessment item became minimal. Every member of the group could upload, view, and edit the content of the website at any time. The university also constantly backed up the website's data, which made it more reliable than the paper notebook. Another benefit of the new platform was that its sitemap made it easier to navigate than flipping through a binder. A group's main hyperlink bar can be seen in Figure 1. This type of navigation increased the potential for exceptional organization in the notebook.

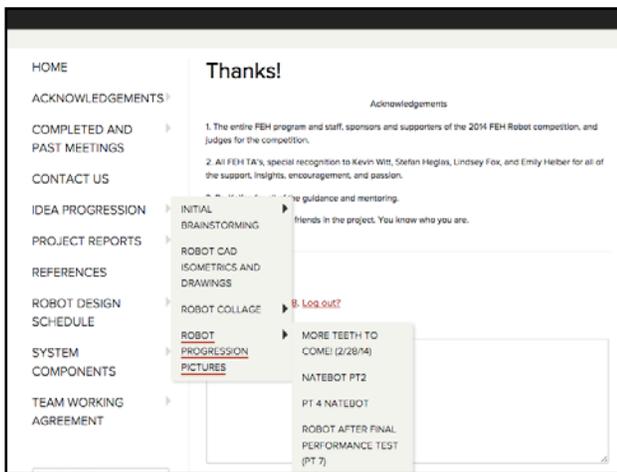


Figure 1: Example of navigating the website.

In addition to the navigation possibilities, the website's multimedia capabilities were greatly enhanced using the electronic platform. Full color pictures and 3D renderings of the robot could be included, which was previously a huge challenge with the paper journal. Some of these elements even contained interactive features where users could rotate the images in the electronic environment. An example of a picture included in one group's notebooks is included in Figure 2. Note that in the electronic format adding a photo along with accompanying text was extremely easy. This allowed students to

not only showcase their robot but explain its functionality and even their decision making process.

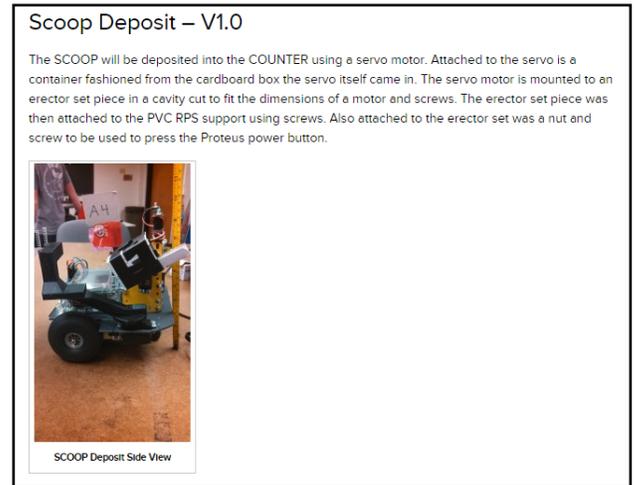


Figure 2: Example description of robot mechanism with photo.

An example of a 3D model that could be manipulated in the electronic format can be seen in Figure 3. Once downloaded, this 3D model could be rotated about a 360-degree axis and zoomed in to reveal its details. This could be done in a simple PDF reader allowing an enhancement to the notebook that would be impossible to achieve in the paper form.

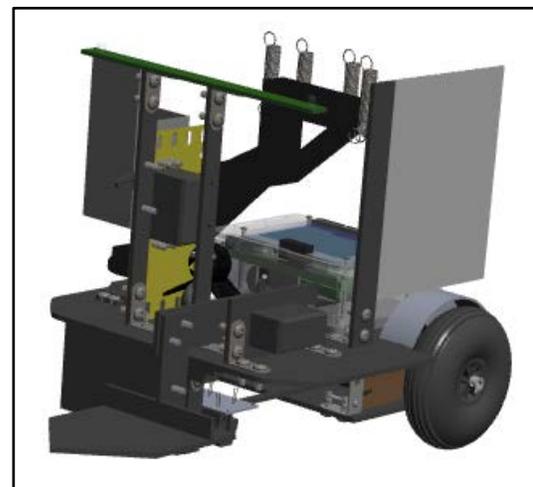


Figure 3: An isometric view of a robot.

Another goal of the notebook, both in the paper and electronic forms, was to allow

students to have materials to show to potential employers during the interview process. The electronic notebook achieved this purpose better than the physical notebook did. Currently, all of the notebooks are available online and can be accessed with a password. In the past, only one member of the team could keep the original notebook and would have to physically bring it to meetings to showcase their work. In the electronic format, a website link and the password can easily be shared via email or simply included on a resume.

The electronic notebooks allowed for a seamless demonstration of the robot design experience. By clicking and scrolling, students could show off the entire progression of their schematics and a final video of their robot in action. This proved to be much easier than flipping through many pages and needing to include multiple photographs to describe the functionality of the robot. The clarity of the contained pages was also vastly improved in the electronic form compared to the paper form. Instead of the drawings being printed and separated by page breaks, images could be placed together directly on the website. An example can be seen in Figure 4.

Methods

To assess the impact of the electronic notebooks compared to the traditional paper notebooks, we developed and implemented a survey that was created using backwards design [14] and Suskie's [15] criteria for good assessments. Suskie [15] summarizes good assessment as: (1) concentrating on and coming from clear and important objectives, (2) cost effective in terms of money and time, (3) producing truthful and accurate results, (4) utilized, and (5) valued. We used these items to design the original project regardless of platform (i.e., electronic or paper) and subsequently the survey. First, the learning objectives of the project regardless of paper or electronic platforms were:



Figure 4: Working drawing set of a robot.

After completing the notebook students will be able to:

- Collaborate with their peers in writing.
- Share their work with others.
- Use electronic data management systems (Google Docs, DropBox, etc.) to document the design process.
- Showcase the progress of their robot project.
- Explain the importance of documentation in engineering design.

Using these learning objectives, we took a backwards design approach [14] to evaluate the elements of the notebooks and then created survey questions specifically targeted to our learning objectives. The bullets above remained the same, but in the survey, we prompted students with “Now that I have completed the notebook, I can...” This allowed us to specifically target each learning objective in the survey. These questions were answered on a 5 point Likert-type scale.

Keeping with Suskie's [15] criteria, we also asked questions about cost, results, use, and value. Those questions were also answered on a 5 point Likert scale. Those questions were:

- I would have liked to spend more time completing the notebook. (Cost)
- The notebook took away needed time from the other elements of the robot project. (Cost)
- The notebook in general is a good representation of the robot project. (Results)
- Our notebook is a good representation of the work I put into the robot project. (Results)
- The notebook process has improved my awareness of design. (Use)
- Creating a notebook has helped me relate my technical skills to my professional skills. (Use)
- Our notebook will be beneficial when applying for a job. (Value)
- In my opinion, updating our notebook was an important component of my learning. (Value)

By asking these questions and the questions above related to the learning objectives, we were able to create a survey to evaluate the effectiveness of the notebook both in its paper and electronic form. We recognize that there is the potential for respondents to give only positive responses to this type of survey as it may be seen as a reflection of themselves and their work. Specifically, there is the potential for students to report that a tool is useful even when it has detrimental effects. We believe the potential for these limitations exists both for the paper and electronic notebooks reducing its effect in our findings related to comparison; however, it is a limitation that must be considered when examining the results for just the paper or just the electronic notebooks.

Five out of nine sections of FEH with approximately 32 students each implemented the electronic notebook. The survey described above was distributed to all students across both

the electronic notebook sections and traditional paper sections to assess students' perceptions of the notebooks in an end of the course survey. Along with the questions that were included to measure the learning objectives and criteria of good assessment, open ended survey questions were also asked to gather additional details about the notebooks that were not captured elsewhere that could be used for future refinement of the notebooks. The survey was developed, distributed, and analyzed in accordance with an IRB approved protocol. In total, we received 216 (Electronic=124, Paper=92) responses to our survey (a response rate of 75%).

After the survey was conducted the results were analyzed using a Mann-Whitney U test. This test was selected because an assumption of normally distributed results could not be made. This nonparametric test was used to determine which statements resulted in statistically significant differences between the students who completed the paper notebook and those who completed the electronic notebook. A p-value < 0.05 was used to determine which statements had statistically significant differences. Charts were made showing the distribution of responses for each statement; however, only statements that were statistically significant are presented with the complete response distribution in this paper.

Results and Discussion

The results of the survey were analyzed first by examining the mean Likert value and the standard deviation of responses. Figure 5 displays the mean Likert responses for the learning objective survey statements along with the standard deviation of responses. From Figure 5, it can be seen that both the electronic and paper notebooks appeared to meet the learning objectives since all these statements resulted in a Likert mean above 4.0 (agree). This finding is encouraging demonstrating that the new notebook platform did not lower achievement related to the learning objectives for the assignment.

The results between the paper and electronic notebook populations did not result in statistically significant differences (p -value < 0.05) for the course objective statements except for the statement about using the electronic data management systems. In this statement, the

electronic notebook students report a higher average agreement (4.56 mean) than the paper notebook students (4.22 mean). Figure 6 shows the distribution of the student responses to this specific statement.

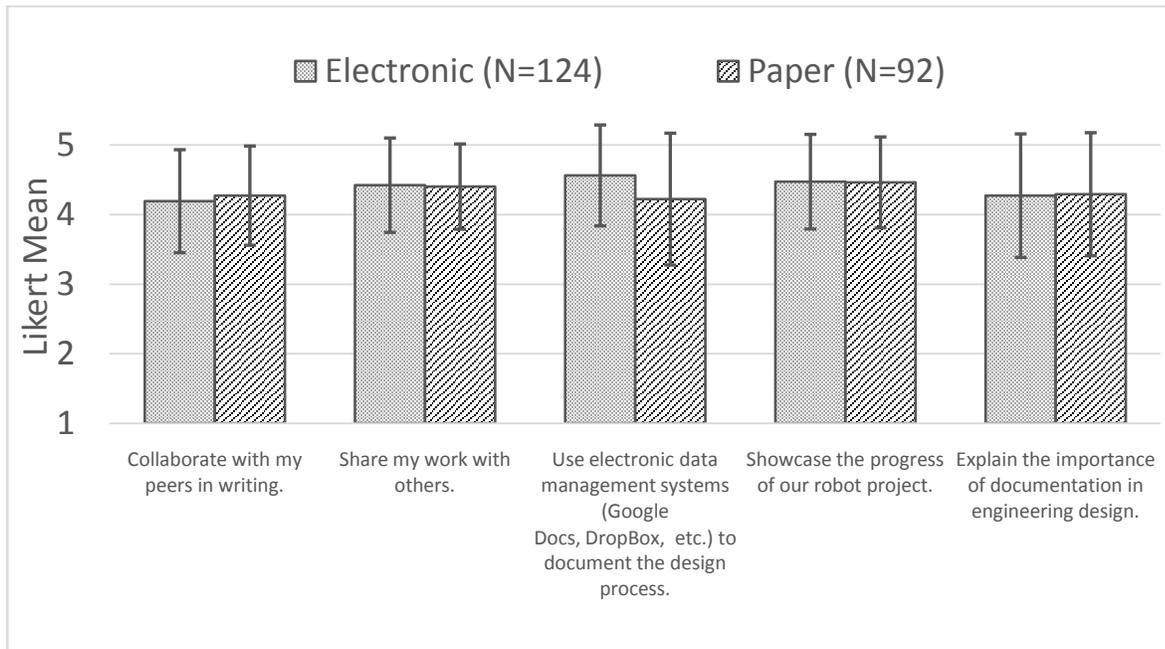


Figure 5: Questions related to learning objectives.

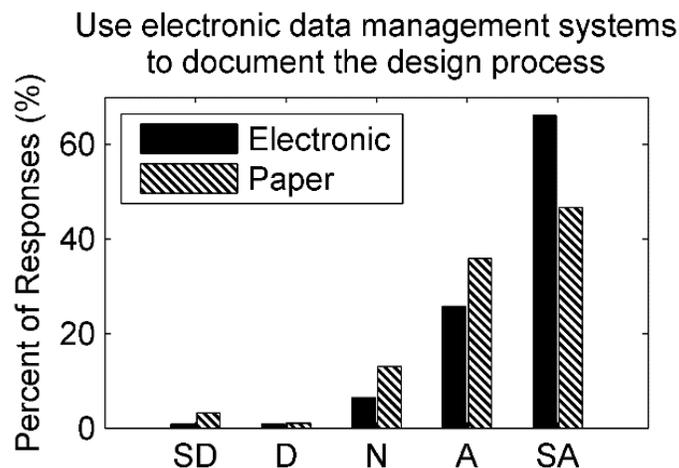


Figure 6: Distribution for questions about electronic data management systems (SD-Strongly Disagree, D-Disagree, N-Neutral, A-Agree, SA-Strongly Agree).

It can be seen here that there is a larger percentage of students who completed the

electronic notebook that strongly agreed with the statement compared to those that completed

the paper notebook. This relates specifically to the goal of wanting the notebook to better interface with other tools utilized in the course. Based on these findings, the electronic notebook is a better tool than the paper notebook for encouraging the use and combination of various tools in the course.

Figure 7 shows the Likert mean and standard deviation distribution for the cost, results, use and value statements. Note, the one statement that was presented as a negative in the survey is reverse coded. Again, the results of the paper and electronic notebooks were generally positive; however, compared to the learning objectives these means were lower typically between 3.0 (neutral) and 4.0 (agree). Despite being lower, the results were generally positive indicating that the notebook is a form of good assessment according to Suskie's [15] criteria. The statement that resulted in the highest mean for both the electronic and paper notebook populations was that the notebook was a good representation of the robot project. Because the

notebook is supposed to be a detailed document of the entire project, this result is encouraging.

There were two statements that resulted in a negative response. Students with both paper and electronic notebooks indicated that they generally did not want to spend more time with the notebook and that it did take away time from the other elements of the project. This is the one area related to good assessment that can be improved. The cost of the notebook seems to be too high whether it is in the paper or electronic form.

All of the cost, results, use, and value statements did not have statistically significant differences ($p\text{-value} < .05$) between the student responses from those that completed the electronic notebook and those that completed the paper notebook. This supports that the new electronic form of the notebook did not decrease elements of good assessment compared to the paper notebooks (i.e., while we did not see big gains, we did not cause harm). Further work is needed in this area to improve the assignment.

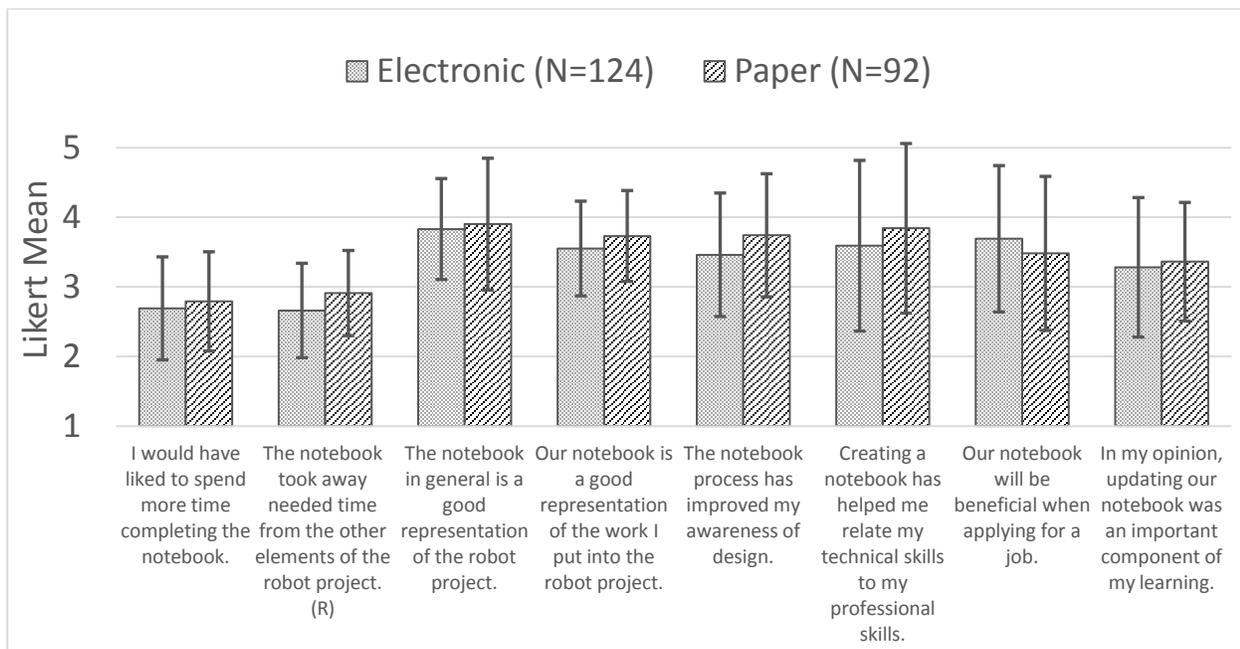


Figure 7: Cost, results, use and value statements (the (R) symbol indicates a response that was reverse coded).

Future Work and Conclusions

The robot project is only one of many design projects offered in first-year engineering at this university. In the future, we will expand the use of the electronic notebooks to all of the robot course sections and to all of the design projects due to its ease of use and potential for impact. We also hope to develop materials to encourage students to further develop their technical communications skills by having them critically think about website and video design. Additionally, we hope to collect additional assessment data to investigate the long term impact and use of the electronic notebooks (e.g., do students actually use them in interviews). Finally, we hope to incorporate elements of EPs into our electronic notebooks to give students a platform to reflect on their design experience and their personal development. With these changes, we believe that the electronic notebook will be a better assessment tool than the paper version.

To ensure that technological enhancements to our courses provide added educational benefits, critical assessments of changes must be conducted. This work is an example of that where a survey was used to evaluate the impacts of an electronic notebook that replaced a traditional paper notebook. Based on our results, the initial implementation is a success, however there are still areas for improvement which will guide our deployments of electronic notebooks in our courses.

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