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Supporting Team Based Learning Using Electronic Laboratory Notebooks: Perspectives From Transnational Students

RAMI GHANNAM[1], (Senior Member, IEEE), SAJJAD HUSSAIN[1], (Senior Member, IEEE), HUA FAN[2], (Senior Member, IEEE), AND MIGUEL ÁNGEL CONDE GONZÁLEZ[3]

[1]Engineering Education Research Group, James Watt School of Engineering, University of Glasgow, Glasgow G12 8QQ, U.K.
[2]School of Electronic Science and Engineering, University of Electronic Science and Technology of China, Chengdu 611731, China
[3]GRAIL Research Group, University of León, 24071 León, Spain

Corresponding author: Rami Ghannam (rami.ghannam@glasgow.ac.uk)

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ABSTRACT Today's engineering industries require graduates with a broad range of soft skills, which include teamwork, communication and integrity. Therefore, more accreditation bodies now recommend team-learning activities to be embedded in their engineering programmes. However, hardworking students often find group projects demotivating, especially if their contributions are not accurately reflected in their individual grades. To address these issues, we demonstrate that Electronic Laboratory Notebooks can be used to promote student collaboration and teamwork on a group project. They can also help instructors assess student contributions fairly. During our investigations, we noticed that students have used Electronic Laboratory Notebooks as social interaction tools that enable text, data, images and recorded audio to be exchanged. Consequently, we describe the experiences of 58 transnational undergraduate students in using six different software products for a team-based learning activity. According to our investigations, Electronic Laboratory Notebooks had a positive impact on supporting Team Based Learning in a new electronic engineering course. The outcomes of our investigations can help create effective teaching and learning resources for undergraduate students in Electronic Engineering. They can also help staff members make evidence-based decisions regarding the introduction of Electronic Laboratory Notebooks in undergraduate research activities.

INDEX TERMS Engineering education, active learning, teamwork, electronic laboratory notebooks.

I. INTRODUCTION

Real world engineering projects are usually tackled by interdisciplinary teams that strive to find solutions to ill-bounded problems, which are not clearly defined [1]. This is different from classical textbook problems that engineering students are typically exposed to. Rarely do engineers work individually and collaboration is often necessary [2]. Teamwork, which is often described as the ability for individuals to collaborate effectively, is an increasingly important attribute required by today's businesses [3]. In fact, it is one of the competences most appreciated by higher educational institutes due to its importance in professional engineering [4]. Without doubt, an effective team increases the probability of achieving the intended outcomes for any project, product, service or learning process [5]. Therefore, engineering accreditation bodies now require university programmes to demonstrate the development of student teamwork skills, regardless of whether graduates decide to pursue a career in industry or academia [6].

Despite its importance, few engineering programmes introduce team-based learning (TBL), which has effectively promoted teamwork skills in engineering education [6]. In fact, the implementation of TBL has enabled more students to pursue engineering degrees [7] and has demonstrated an improvement in student exam performance [8]–[10]. Paradoxical though it may seem, the literature has demonstrated more than half of all engineering programmes lack any form of active learning [11]. However, the development and acquisition of teamwork competency is essential in educational and professional contexts, especially due to the following three reasons:

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1) Teamwork requires students to collaborate and share information with each other, which ultimately leads to improved student learning and achievement [12], [13];
2) Commercial organisations expect to hire graduates with effective teamwork skills, since engineering organisations typically work in teams to deliver a product, solution or service [14];
3) According to the EU's Bologna Declarations in 1999, 'Teamwork' was a key graduate attribute that students should develop during their higher education studies [15]–[17].

Another important fact is that China is currently producing over eight million Science, Technology, Engineering and Mathematics (STEM) graduates each year [18]. This figure far exceeds the total number of STEM graduates from all Western countries [19]. According to the literature, additional efforts are required to guarantee that these engineering graduates develop the skills required by the global employment market [20], [21]. We therefore designed a dedicated module to help Chinese students cultivate the necessary teamwork skills, which was called Team Design Project and Skills (TDPS) [22]. This course forms part of a transnational education (TNE) programme between a Scottish university located in Lanarkshire and a Chinese university located in the Sichuan province. Given a predefined budget, the aim of this course was to develop the necessary teamwork experience in designing a rover that performs specific technical tasks.

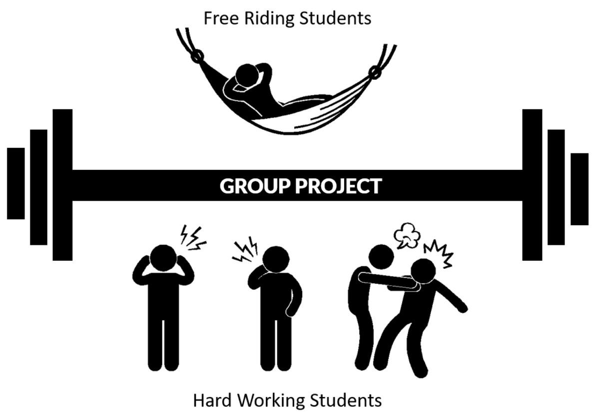

FIGURE 1. Unpleasant feelings towards group projects due to free riders. Hard working students bear the full weight of the group project, while free riders reap the benefits with minimal effort.

Nevertheless, there are challenges in facilitating and assessing team projects, especially in a transnational context. For example, how can students effectively collaborate and share information? How can instructors assess individual learning and performance? How can the learning process, rather than the final report or product be effectively assessed? How can "free riding" students (c.f. figure 1) be avoided? Our study therefore addresses several questions about the development and assessment of teamwork skills in electronic engineering students. In particular, our approach relied on encouraging students to maintain a carefully documented Electronic Laboratory Notebook (ELN), which claims to facilitate collaboration and enable instructors to view an accurate record of each student's individual contributions to the group project. In particular, we focus on showcasing transnational student experiences after using ELNs for one semester. Such transnational initiatives are gaining popularity among universities and it is vital to ensure that student learning is not compromised due to remote education [23]. In our case, we recommended two commercial and four open-source software tools, which were easily accessible to students in China. Our manuscript therefore showcases how students have perceived these tools in facilitating and supporting team based learning (TBL) in a TNE programme.

In the following sections, our manuscript provides an overview of ELNs and how they have been previously used in different teaching programmes. Next, we describe the instruments used to gather student feedback regarding the effectiveness of ELNs in promoting teamwork, and how they can assist instructors in assessing student contributions fairly. The results of our investigations are demonstrated in section 5. Finally, the manuscript ends with concluding remarks and future recommendations.

II. RESEARCH CONTEXT

In an effort to fulfil professional accreditation requirements and to address the teamwork development issues mentioned in the previous section, a 17-week course for 3rd year students called Team Design and Project Skills was developed. In brief, the 10-credit course was designed to achieve the following Intended Learning Outcomes (ILOs):

- To develop a fully functional integrated (microprocessor-based) system. This system involves both hardware and software design.
- To gain experience in the full development cycle of a product, starting from product specification and design through to development, testing and implementation.
- To manage and execute a group project without relying on the instructor.
- To gain essential skills required by the global job market, which include collaboration, teamwork, time management, leadership, as well as oral and written communication.

Students were asked to work in teams to develop a smart rover that follows a meandering path, transmits a radio signal, carries an item, and detects colours, edges and lines. Details regarding the technical tasks were provided in the course handbook and are summarised in the literature [22].

Moreover, to demonstrate student acquisition of the aforementioned ILOs and to ensure that students were graded fairly, all students completed a mixture of group and individual assessments. Both group and individual performances were then reflected in the overall project grade, as suggested in the literature [24]. Students were therefore required to submit: (a) an individual laboratory notebook (10% of the final grade), (b) an individual 500-word reflection report

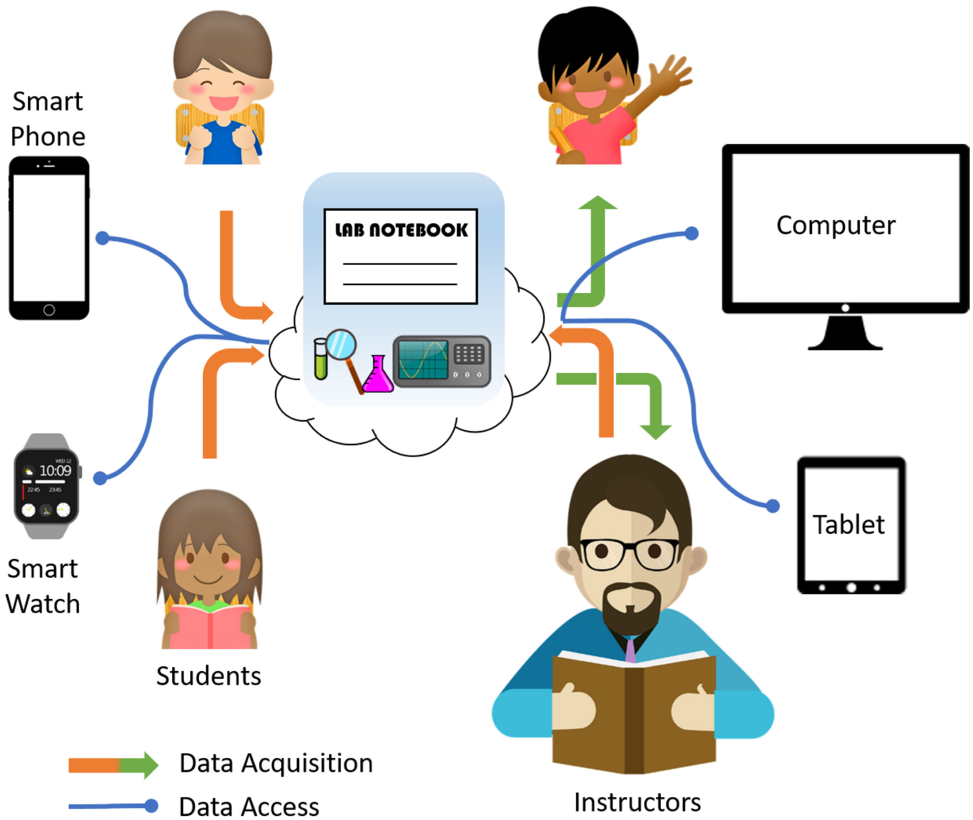

FIGURE 2. ELNs and their accessibility from any location and device. They enable students to exchange information and to collaborate in real time. They also enable instructors to provide feedback and assess student work as it is being performed.

(25%), (c) a 5000-word team report (25%), (d) a 30-minute oral presentation (25%) and (e) a live demonstration of the rover (15%).

Despite this mixture of assessments and according to our previous investigations [22], there were still unpleasant feelings towards group projects due to the presence of "free riding" students, who were not contributing equally to the group project (c.f. figure 1). Moreover, students' paper notebook submissions were disorganised and difficult to read [25], which may be attributed to few students receiving any form of training in notetaking during their pre-university education [26]–[28]. Therefore, since young researchers are perceived as "digital natives," our investigations relied on embracing digital technology and encouraging students to use Electronic Laboratory Notebooks (ELNs) in place of traditional paper based notebooks. In fact, we believe that ELNs can act as social interaction tools that enable text, data, images and recorded audio to be exchanged synchronously. In this context, our work goes beyond existing research in this field, since it aims to showcase how transnational students have used ELNs as a tool to (a) enhance their team learning experience and (b) to demonstrate their individual contributions to a group project in an electronic engineering undergraduate degree programme.

III. STATE OF THE ART

A lab notebook should contain a detailed record of research data. Furthermore, the main advantages of ELNs are well documented in the literature [25], [29]. In comparison to paper-based notebooks, ELNs are software tools that are designed to enable lab work to be easily shared, copied and archived [30]. Since all data is stored in the digital domain, supervisors can monitor student progress effectively and remotely, as the work is being performed, as shown in figure 2.

In fact, there are over 60 ELN products in the market [31], which range from specialist commercial products (such as ChemBytes [32]), to open source (such as elabFTW [33]) and general notetaking software (such as OneNote [34] and Evernote [35]). The reader may refer to the 'ELN Matrix' compiled by Harvard University for a detailed comparison between the main features of 32 different ELN software products [36].

For undergraduate teaching, ELNs have been used to compliment the delivery of a biochemistry course [30], [37]. In the study by Walsh *et al.*, 500 medical students were invited to trial Evernote for six months [37]. According to feedback from 80 students (16% response rate) who participated in the surveys, ELNs were 'easier to use', 'flexible'

Category	Proficient (4-5)	Developing (2-3)	Basic (0-1)	Score
Organisation	• All pages are numbered and dated. • Each experiment or key argument contains title, purpose and brief procedure. • The key arguments are expressed fluently. • Observations, recorded data and calculations are present. • All information recorded in pen not pencil. • Complete table of contents.	• Most pages are numbered and dated. • Some of the key arguments are missing one or two of the following: title, purpose, brief procedure or reference to lab manual. • Recorded data and observations are incomplete in some areas. • Some of the information is recorded in pencil. • Table of contents missing some experiments or key arguments.	• Most pages are not numbered and dated. • Most of the experiments are missing several of the following: title, purpose, brief procedure or reference to lab manual. • Recorded data and observations are incomplete in most areas or not present. • All information is recorded in pencil. • Most experiments are not recorded in table of contents.	
Content	• All data and workings are recorded completely. • All data is recorded and neatly presented with units to the correct number of significant figures. • All calculations and observations are included and neatly presented with details including units and significant figures.	• Workings and observations are not complete and missing important details. • Data is recorded, but is not presented neatly or some are missing units or the correct number of significant figures. • Findings and observations are included, but are not presented neatly or missing details.	• Workings and observations are mostly missing. • All data is not recorded and not neatly presented with missing units and have incorrect number of significant figures. • Calculations and observations are not included or are very sparse with no units and are incorrect.	
Analysis	• Data is explicitly analysed, methods of analysis are described with appropriate detail. • Calculations are presented neatly. • Graphs and images are properly labelled, scaled and annotated. • Sources of error are explored and considered when evaluating data.	• Data analysis is implied and methods of analysis are not described or properly used. • Calculations are sometimes not complete. • Graphs and images are included, but are not properly labelled, scaled and annotated. • Sources of error are explored, but they are inadequate or incomplete.	• Data analysis is not included. • Calculations are missing. • Graphs and images are missing or grossly incorrect. • Sources of error are not explored.	
Commentary and Conclusions	• Results are explicitly interpreted and compared with literature data. • Conclusion is written in coherent manner. • Discussion of any limitations and any problems encountered, explaining how they could be overcome and how they contributed to the results.	• Results are interpreted but interpretation is sometimes missing. • The key arguments are expressed well. • Some understanding shown and key arguments agree with the presented data.	• Conclusions are not logical and/or do not agree with data presented. • Conclusions are written in non-coherent manner with many spelling and grammatical errors.	

FIGURE 3. Snapshot of mark scheme used for assessing the lab notebooks. Both ELNs and paper notebooks were assessed according to the same four criteria, which were "Organisation," "Content," "Analysis" and "Commentary."

and 'easier to share information' in comparison to traditional PBNs.

In another teaching programme, LabArchives [38] has been used to compliment the laboratory teaching of a graduate course on Bioprocess Engineering [39]. According to surveys that were completed by 32 students (84.2% response rate) in 2015 and 23 students (70% response rate) in 2016, students generally showed favourable experiences using ELNs.

However, in each of these previous investigations only one software program was evaluated. Moreover, none of these software programs were trialed on electronic engineering students. This could be attributed to historical reasons, where large pharmaceutical industries drove the ELNs market, and their researchers still make up the largest proportion of ELN users today [37]. We therefore set out to showcase the effectiveness of ELNs via students who enrolled in a third-year electronic engineering course called Team Design and Project Skills (TDPS). We chose this course for our investigations, since students were required to develop a smart rover in teams of eight people. Therefore, we aimed to investigate whether ELNs (in general) can be used to assess each student's learning process and their individual contributions to the group project. Further details regarding our sample and our case study are outlined in the methodology section of our manuscript.

IV. METHODOLOGY

A. PARTICIPANTS

To generalise findings within the Electronic Engineering department, we chose to carry out our investigations in a 3rd year compulsory course called TDPS. A total of 320 students were enrolled in this course, who were divided into groups of eight to develop a rover that accomplishes a set of technical tasks. Similar to the investigations by Conde [5] and Riley [39], students chose their own team members and assigned a Project Leader, who was responsible for managing the team and for sharing their notebook with the entire team. The course was delivered for one semester (17 weeks) in the 3rd year of study. The laboratory notebook weighed 10% of the final grade and the mark scheme used to assess these notebooks will be explained in next section. Students were required to interact with each other in their groups and upload their completed assignments in Moodle.

B. PROCEDURES

During the first two weeks, students attended six lectures that explained the course's core concepts. The assessments and their mark schemes were also explained to all 320 students during the first introductory lecture. All the assessments and mark schemes were made available to students via Moodle during the first week of instruction. Student laboratory notebooks were assessed according to four main criteria, which were "organisation," "content," "analysis" and "commentary," as shown in Figure 3. Furthermore, students were given recommendations for how to maintain a notebook during the third lecture. We introduced the general concepts of ELNs and gave students the option of using them instead of traditional PBNs. For the purpose of our investigations, we recommended three commercial (LabArchives, RSpace and OneNote) and three free (SciNote, Benchling and elabFTW) software packages that were easily accessible to students in China. The licensing costs for using the commercial packages were covered by our Scottish university.

Our objective was not to test the software products from a technical perspective, but to evaluate their effectiveness in identifying individual learning within a group project, as well as facilitating teamwork. For example, was each student able to make note of all the technical content relevant to their part of the project? Was their data neatly organised? Were they able to share this data easily and effectively with other team members? Were they able to analyse this data and draw the necessary conclusions?

Three instructors were involved in the delivery of this module. As previously mentioned, students were given the choice of using only one of these software products for a period of 17 weeks to record their progress and all their results. Students were not permitted to switch ELN products during this period. In the end, 58 students volunteered to trial the ELNs and to complete the surveys (18.12% response rate). This far exceeds the 8% response rate considered acceptable for a class size of 300 (10% sampling error and 80% confidence level) [40].

Moreover, we obtained the necessary ethical approvals from our Scottish university to pursue this investigation. An online consent form was distributed to participants before undertaking this study. Participants volunteered on an individual basis and were informed that all collected information would be anonymous and confidential. They were also informed that their participation would not affect their grades. The questionnaires were distributed in the first month of the second semester. Details regarding questionnaire design and development are provided in the next section.

C. DATA COLLECTION METHODS

Our study aimed to understand student experiences with ELNs. After consulting with other staff members in pedagogical research within the College of Science and Engineering, we developed an online survey to evaluate the effectiveness of ELNs via 20 carefully constructed questions, which were tested for clarity and relevance. Our survey questions were adapted from validated ELN questionnaires by Walsh [37], Riley [39], Puccinelli [41] and Okon [42], as well as general software questionnaires developed by Conde [5] and Jung [43]. Each of the previous ELN investigations relied on testing a particular ELN product. However, in our case, we were interested in generalising findings. We therefore obtained the necessary ethical approvals from our Scottish university to carry out this investigation. Our open questionnaire was available to students in week 12 of the course and it was divided into five sections that were designed to capture student feedback regarding their experiences using different ELN software tools. The full survey is available in the 'Supplemental Materials' section.

The first section consisted of four multiple-choice questions (MCQs) regarding laboratory notebooks in general. Similar to the investigations by Puccinelli [41], the first question asked students whether they were aware of what laboratory notebooks were using a simple Yes/No response. The next question asked students how they usually kept track of their experimental work. Four options were given to students, in addition to a fifth "other" answer field. The third question was adopted from Walsh and asked students what were their reasons for not switching to ELNs via six possible responses. However, in our survey students were asked to select only one answer, instead of "select all that apply" to better pinpoint why students have not switched to ELNs. Finally, the last question in this section was adopted from Riley [39], which asked students whether they believed laboratory notebooks (in general) can help instructors assess student work and help instructors resolve student grade appeals.

The second section consisted of four MCQs, which aimed to understand the students' overall satisfaction with their ELN product. Students were asked what product they chose, why they have chosen it, how much they would be willing to pay for the product and how long it took them to become familiarised with this product. Furthermore, Riley et al developed the comfortability (CF) index [39], which was the product of the time taken to be familiarised with the software tool (T) and the number of students (N), such that $CF = T \times N$.

The third section consisted of six self-assessment questions, where students were asked to rate their overall ELN experience via a 6-point Likert scale ranging from 0 (poor) to 5 (excellent). We preferred to use this scale to avoid students giving "neutral" answers, so that a "0" indicates a complete absence of a particular feature. A larger scale was not used to avoid extra effort and fatigue from the student perspective 40. Our questions were adopted from a validated questionnaire by Conde [5], as well as another study for testing the quality of software products by Jung [43]. Thus, students were asked to rate their experience in terms of ease of use, flexibility, user-experience, skilfulness with the software, data sharing and collaboration, and whether they were able to maintain a better record of their experimental data in comparison to their past practices.

The fourth section consisted three MCQs, which aimed to understand what features they liked and disliked about ELNs. The first two questions were adopted from research by Walsh [37]. Among the features, students were given the answer option of "Ability to share information with other members." The third question in this section asked students which ELN features benefited instructors most. Eight possible answer options were given to students, including "the ability to assess each team member's contributions fairly."

The fifth and final section consisted of three MCQs that aimed to understand student recommendations for the future via a Yes/No response. Similar to the investigations by Okon [42], students were asked whether ELNs enabled them to maintain a well-organised notebook with all the embedded text, maths and graphics. The second question asked students whether they would continue to use ELNs for their final year (capstone) project. Finally, the third question asked whether they would recommend ELNs to other users.

TABLE 1. Percentage of Surveyed Students With Each Answer Choice.

Questions	Yes (%)	No (%)
Before this project, where you aware of either PBNs or ELNs?	88	12
Can lab notebooks help instructors resolve student grade appeals?	90	10

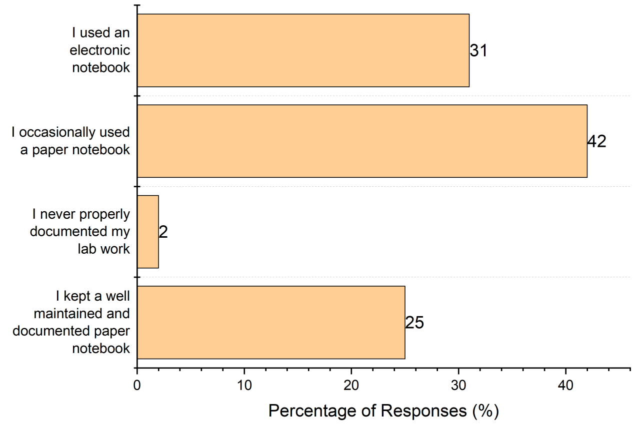

FIGURE 4. Student responses to how they used to keep track of their course project work. The majority of students still used paper notebooks.

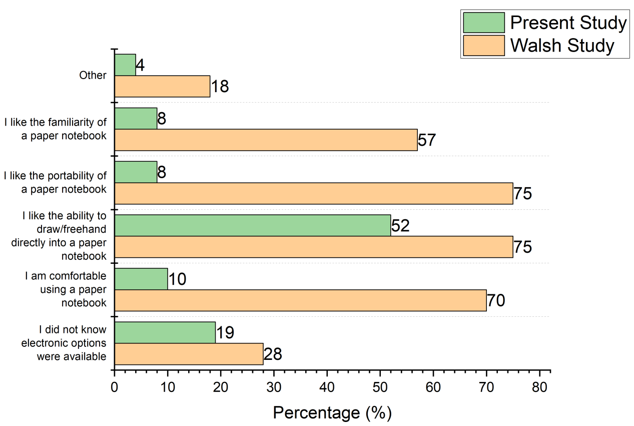

FIGURE 5. Student responses to what are the most important attributes of ELNs. Comparisons with Walsh *et al* are shown [37].

V. RESULTS AND DISCUSSIONS

Figures 4 to 13 show the results of our survey. Interestingly, the vast majority (88%) of our third-year students were aware of either PBN or ELN products. This is clear from the survey results shown in Table 1. Surprisingly, 89.6% (approximately 90%) of students were convinced that laboratory notebooks could help instructors resolve grade appeals, since individual work can be assessed effectively. This could be attributed to the legibility and traceability of each student contribution [39]. These findings therefore agree with those by Riley *et al* during their experimentation with LabArchives during a biomedical engineering lab [39].

Moreover, approximately 31% of our surveyed students have previously used an ELN product, as shown from the results in figure 4. This is much higher than the figures reported in the literature, where it was claimed that fewer than 5% of academic labs use ELNs [30]. In fact, this finding is acutely different to previous results from a Biomedical Engineering Laboratory surveying 200 students (sophomore and senior) at the University of Wisconsin-Madison [41], where 98% of students confirmed they never used them. Clearly, our students in China were aware of ELNs and have used them in the past. However, almost 44% of students either occasionally or never kept a regularly maintained and documented notebook. Again, this confirms the findings in the literature [26], suggesting that few students receive any form of training in notetaking during their pre-university education.

Furthermore, the most popular reason for students not switching to ELNs was their preference to draw directly onto a paper notebook, which confirms the findings in Walsh's study [37] (as shown in figure 7). In Walsh's study, students also preferred the portability of a notebook. However, this was among the least important reasons preventing our transnational Chinese students from switching to ELNs. According to our surveys, 19% of our surveyed students never knew ELNs existed, which is the second most popular reason for students not switching to ELNs. In fact, this percentage is still much lower than the figure reported by Walsh (28%) [37], as shown in figure 5.

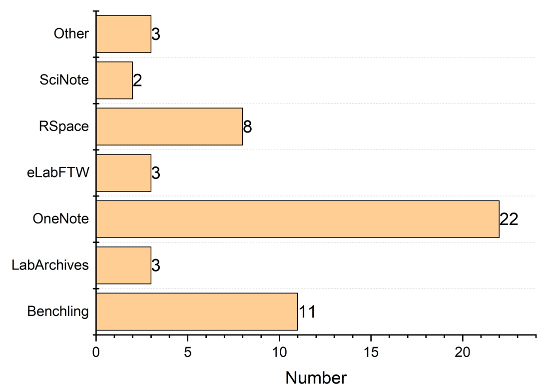

FIGURE 6. Student responses to which ELN product they used. The majority of students preferred non-specialist notetaking applications such as Microsoft OneNote.

Moreover, 49% of students chose OneNote for their projects and 12% of students selected the "other" option, as shown in figure 6. When asked for further details, one student mentioned using MarginNote, another student mentioned using Notability. Moreover, two students mentioned using eLabFTW and another mentioned using GoodNotes.

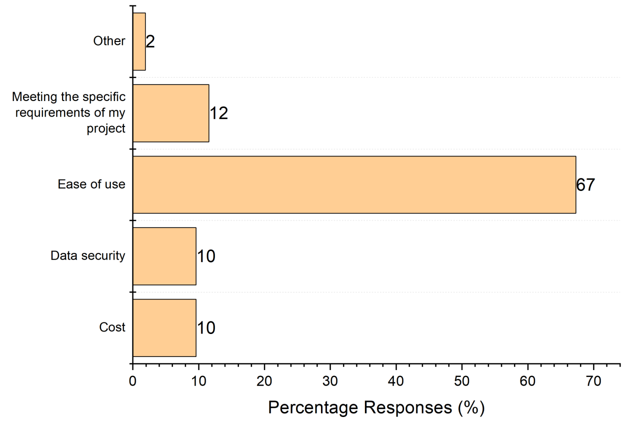

FIGURE 7. Student responses to why they did not switch to ELNs. 'Ease of use' was perceived as the main impediment.

Thus, more than half our students preferred to use notetaking or note-making software programmes. Although our Scottish university provided licenses for RSpace and LabArchives, only 19% of students chose these products. This could be attributed to the higher learning curve required for using such specialised software. When asked about the major criteria determining how students selected an ELN, almost 67% explained that the "Ease of use" was the most important factor, as shown in figure 7. "Cost" and "Data Security" were among the least important reasons.

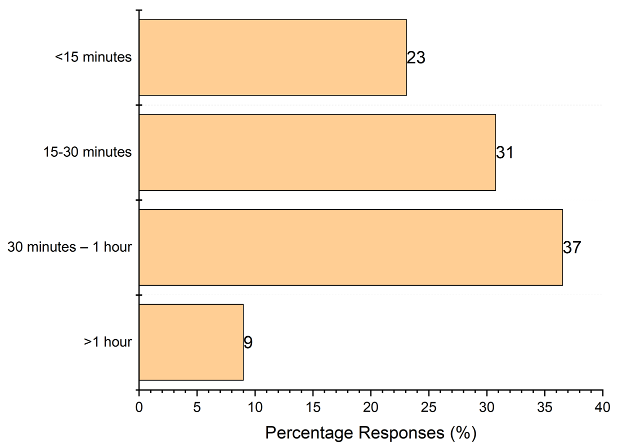

FIGURE 8. Student responses to how long it took them to become familiarized with the product. The average time was ≈ 32 minutes.

As previously mentioned, "Ease of Use" is an important factor determining how well student adopt ELNs. According to our findings shown in figure 8, 47% of students needed more than 30 minutes to become familiar with the tools. Again, this is perhaps why the majority of students preferred the notetaking applications. In fact, according to the survey by Riley, approximately 60% of students needed two weeks to become familiar with LabArchives. Naturally, this is a long learning curve that will deter students from adopting a tool within a 17-week project. In our case, the mean time was approximately 32 minutes, the median time was 15-30 minutes and the mode was 30 minutes to 1 hour. The standard deviation for this data was approximately 15.2.

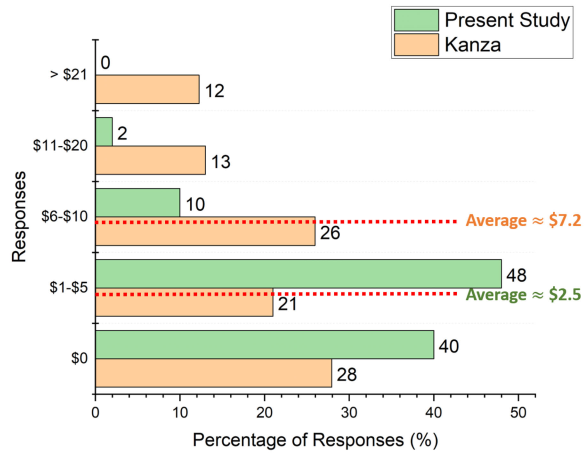

FIGURE 9. Student responses to: "what monthly subscription would you pay for ELNs?." Comparisons made with Kanza *et al.* [44]. Our transnational students were prepared to pay almost a third less.

Similarly, 88% of students preferred to pay a subscription fee of less than $5 per month for an ELN license. In fact, according to the results in figure 9, 40% indicated that they would prefer free ELN products. This result confirms previous findings in the literature regarding the hurdles to widespread adoption of ELNs. As mentioned in the literature [44], cost is the dominant issue, which gives paper based notebooks a clear advantage [29]. Our findings are therefore different from those by Kanza [44], where 52% of surveyed users indicated that their willingness to pay more than $5 per month in licensing fees. In our case, only 12% of surveyed students were willing to pay this fee. The average fee our students were willing to pay was approximately $2.5, which is almost a third lower than the average amount respondents in BioSistemika ELN survey were prepared to pay ($7.2) [44]. Of course, this could be attributed to differences in living standards between Asia and Europe.

Moreover, thanks to ELNs, the majority of our surveyed students (54%) confirmed that they were able to maintain better than "good" notetaking skills in comparison to the past, as shown from the Likert scale results in figure 10. This could be attributed to the availability of templates, making it easier for students to organise their work. However, 15% rated their notetaking skills as "poor" with ELNs. Perhaps this group of students used specialist ELN software products, which required a steep learning curve in the beginning. On average, 92% students rated their ELNs as either "good," "very good" or "excellent" in terms of collaboration. In fact, 69% thought they were either "very good" or "excellent" for collaboration purposes. Consequently, this could translate to better teamwork skills development.

In general, 49% of students rated their user experience with ELNs as "very good" or "excellent," which is similar to the proportion of students considering ELNs as easy to use

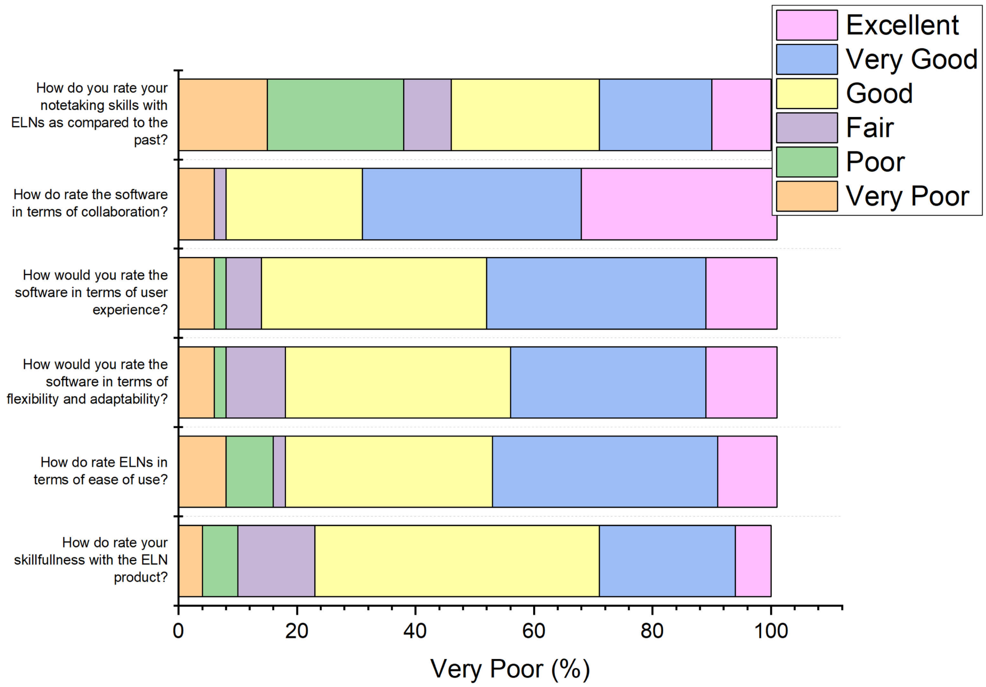

FIGURE 10. Student responses to Likert scale questions. Students were asked to rate their ELN user experience. Clearly, the majority of students indicated that ELNs are 'Excellent' or 'Very Good' tools for collaboration purposes.

tools (38%). It is therefore no surprise that ELNs are generally gaining popularity among researchers, with user numbers being doubled every year for products such as Benchling [45].

Nevertheless, after almost 4 months of using their ELN products, 23% of our students still felt that they were not entirely skilful in using their products. This proportion rated their skilfulness as "very poor," "poor" or "fair" and may be attributed to their use of specialist software tools that require a longer learning curve.

According to approximately 52% of the surveyed students, the biggest advantage of the ELNs was their "ability to share information with other lab members." This reinforces the argument that ELNs are great tools for collaboration purposes, as confirmed by Riley's study [39]. Furthermore, according to our students, the second most important feature of ELNs is their "accessibility from any computer or mobile device," as shown from the results in figure 11. Coincidental, Riley *et al* showed that this was the most important benefit of ELNs. Their study's second most popular advantage was the ELN's ability to search information easily. These contrasting results could be due to the differing educational backgrounds of the students using these products. As previously mentioned, the pharmaceutical industry was the main driver of the ELN market, where enormous amounts of biological and clinical data are typically generated [46]. Therefore, it is perhaps important for researchers in this industry to easily search for information and to access that information from any connected device. In the case of our electronic engineering students, due to the distributed nature of engineering

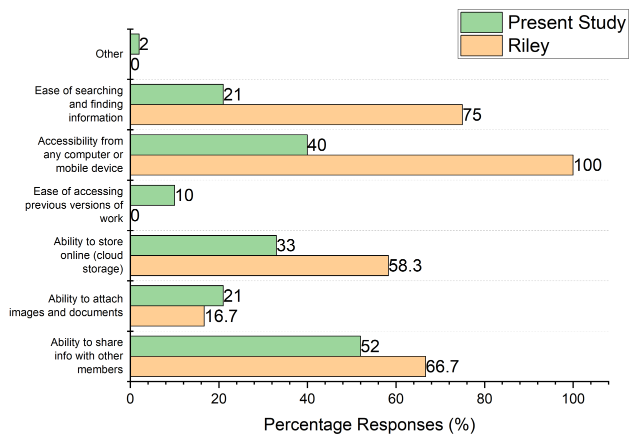

FIGURE 11. Most important features of an ELN. Comparisons made with Riley *et al.* [39]. Ability to share information with others was most important feature in our study.

knowledge and projects, engineers need to collaborate effectively together to complete a project [47].

Our investigations also revealed interesting drawbacks to ELNs, as shown from the results in figure 12. According to our surveys, students were not in favour of their rigidity (46%), their inability to draw freehand (21%) as well as their complexity (33%). As previously shown from the results in figure 7, the most popular reason for students not switching to ELNs was their liking to drawing freehand on PBNs. Clearly, the software products our students trialled were still incapable of satisfying their needs. In fact, Riley's

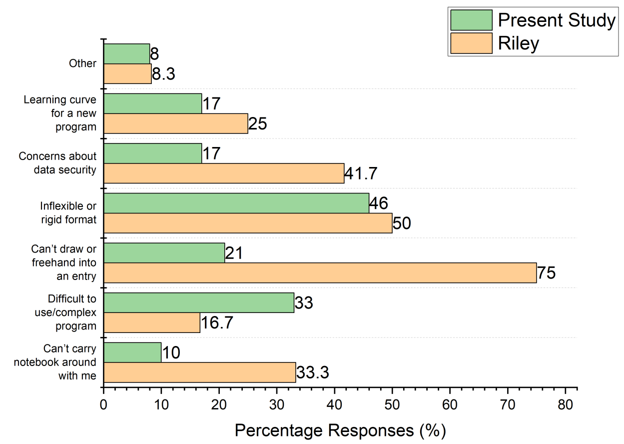

FIGURE 12. **Student responses to: "what were the major pitfalls of the software package you used?." Comparisons made with Riley *et al.* [39].**

investigations indicated that the main disadvantage of using the LabArchives ELN was its inability to draw freehand. Despite engineering students being more accustomed to using technology in comparison to other disciplines [48], additional possible reasons, which have not been considered in our surveys, may include a reluctance to use digital technology in general [49].

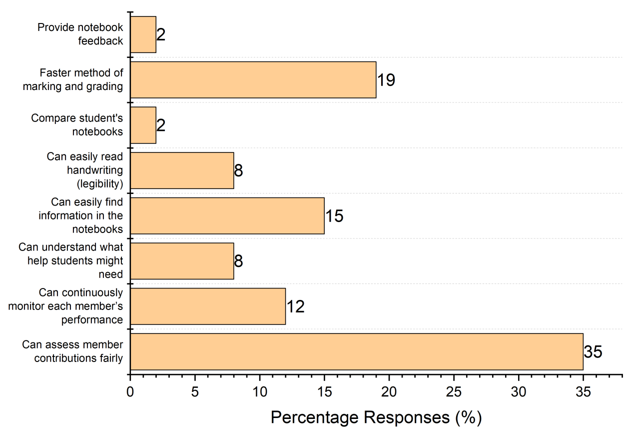

FIGURE 13. **Student responses to: "From the instructor's perspective, what do you think are the major benefits of the software product you used?." The most important feature was the ability to 'asses student contributions fairly'. Student expectations therefore agreed with instructor feedback.**

The survey results shown in figure 13 have revealed that students believed that ELNs are useful tools that can help instructors assess their contributions fairly. This was a major concern for our students working in groups. Secondly, students strongly believed that ELNs can help instructors grade their work quickly and more efficiently. A similar finding was reported by Riley *et al.*, where LabArchives was shown to facilitate real-time monitory of experimental data, as well as "ease of grading and feedback."

Moreover, we discovered that our transnational students were keen on knowing their grades for submitted work promptly, as can be interpreted from the results in fig. 13. Interestingly, our students were far more concerned with knowing their grades (19%) than receiving feedback from their instructors, since only 2% students were interested in receiving written "notebook feedback." Further investigations are therefore necessary to understand why this is the case.

As for instructor feedback, instructor A mentioned that 'OneNote helped me keep track of student progress on their projects. It allowed me to quickly go through their work and helped me guide them efficiently.' Instructor A also indicated that 'When grading students, OneNote history was extremely useful, particularly to assess students' punctuality, technical details on the tasks they performed, rigour etc. The use of electronic record keeping of the meetings has helped me a lot to fairly assess my students and this is evidenced from no appeals from the students at all recently.' Instructor B also mentioned that 'LabArchives and RSpace were very versatile tools with intuitive user interfaces. They enabled me to track student progress remotely, which is very important in a TNE programme. It was also easier for me to read student work in comparison to paper based notebooks. It was great to see students using the LabArchives sketching tool to draw freehand'.

Therefore, in the context of a TNE programme, we believe that ELNs can assist in the development of effective team skills and help instructors assess group activities. It enables better collaboration and productivity between team members. For example, they enable students to share information, search for information and keep track of changes made by other team members, as well as overall project progress. We also feel that ELNs can help instructors assess student contributions more fairly. We believe that they enable transparency and better grounds for student appeals. Moreover, our survey results clearly show student preferences towards non-specialist notetaking or open source software tools (such as OneNote and Notability) in comparison to commercial ELN products. However, further investigations are necessary to determine whether the benefits of these commercial ELNs increase when students are taught the basics of notetaking.

Nevertheless, there are important limitations to this study. The first is concerned with the nature of the projects. Our study has been confined to electronic engineering students. It did not consider the preferences of students in other engineering disciplines, such as civil, mechanical or aerospace engineering. Second, this study was confined to the experiences of students in one TNE programme and it did not consider the preferences of other TNE students in China. Third, our study only focused on the experiences of third year students enrolled in one course from the electronic engineering programme. It did not consider the preferences of other students, who might need other requirements. Nevertheless, our intention is that this article provides a framework and some support for others wishing to move their teaching away from traditional approaches. However, prudence requires that instructors should exercise a degree of caution in the adoption

TABLE 2. Percentage of Surveyed Students With Each Answer Choice.

Questions	Yes (%)	No (%)
Would you recommend the ELN software product you used to others?	77	23
Has the ELN software product enabled you to maintain a well-documented lab notebook with all the embedded text, maths, graphs and figures?	91	9
For your final year projects (FYPs), it is mandatory to keep a notebook. Would you prefer to continue using an ELN software product for your FYP?	82	18

of these tools in their curricula, since engineering students are commonly exposed to more technology tools when compared to 'digital immigrants' or students from a non-technical discipline [48]. Furthermore, levels of digital literacy can vary greatly among 'digital natives', and there is evidence to suggest that these assumptions can prove problems in successfully adopting digital technologies in the classroom [49].

Asked whether they would endorse these ELN products, 77% of students generally agreed that they would recommend them to other students for group projects, as shown from the results in Table 2. In fact, 91% of students felt that ELN products helped them maintain a well-documented notebook with all the embedded text, graphs and figures. This result is in agreement with those from a previous study that involved the use of LabArchives for a biomedical engineering lab, where the ELN scored 29.2 points out of 32 for its ability to document data, graphs and relevant discussions [42]. Further confirmation that student experience with ELNs was generally positive is evidenced from their responses when asked whether they will continue to use them the following year for their capstone project, as shown from the responses in Table 2.

VI. CONCLUSION

The article highlights the sharing of good practice in supporting team-based learning using ELNs. We have showcased this via a 3rd year electronic engineering course called Team Design and Project Skills, which was delivered to transnational students in China. We have also discussed evaluative data from students to showcase the positive impact our approach had on experience and learning. In the context of a TNE programme, where academics are involved in block teaching and remote supervision of students, we found multiple benefits of ELNs. For example, they enabled instructors to monitor student progress from anywhere in the world. Instructors were also able to read student contributions more clearly and succinctly, thus enabling more effective grading. Ultimately, these benefits will lead to fewer student appeals and higher student satisfaction. Furthermore, 91% of students agreed that ELNs enabled them to keep a well-maintained laboratory notebook, which is becoming increasingly important for protecting and validating scientific claims. Overall, student experience with ELNs was positive, with 82% of students indicating that they will continue to use them in their final year capstone project.

Moreover, 'Ease of use' had a major impact on students deciding to switch to using ELNs in their educational programmes. Interestingly, we noticed that almost half our sampled students chose notetaking applications such as OneNote, MarginNote and Notability. Our surveys clearly showed that students favoured notetaking applications instead of specialist software products. Further work is therefore required to investigate why this is the case, as well as the features that students liked and disliked most about these applications.

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RAMI GHANNAM (Senior Member, IEEE) received the B.Eng. degree in electronic engineering from King's College, the D.I.C. and M.Sc. degrees from Imperial College London, and the Ph.D. degree from the University of Cambridge, in 2007. He held previous industrial positions at Nortel Networks and IBM Research GmbH. He is currently a Lecturer (Assistant Professor) in electronic and nanoscale engineering with the University of Glasgow. His research interests include energy harvesters and engineering education. He is a Senior Fellow of Glasgow's RET Scheme. He received the Siemens Prize for the B.Eng. degree. He serves as a Scotland's Regional Chair for the IEEE Education Society.

SAJJAD HUSSAIN (Senior Member, IEEE) received the master's degree in wireless communications from Supelec, Gif-sur-Yvette, in 2006, and the Ph.D. degree in signal processing and communications from the University of Rennes 1, Rennes, France, in 2009. He was an Associate Professor with the Electrical Engineering Department, Capital University of Science and Technology (CUST), Islamabad, Pakistan. He is currently a Senior Lecturer (Associate Professor) in electronics and electrical engineering with the University of Glasgow, U.K. He has authored or coauthored more than 60 journal and conference publications along with one authored book, and one edited book. He has more than ten years of academic experience with roles as a principal/co-investigator in several funded projects. His research interests include 5G self-organizing networks, industrial wireless sensor networks, machine learning for wireless communications and technology enhanced student learning techniques. He is a Fellow of the Higher Education Academy and a Senior Fellow of the Recognizing Excellence in Teaching. He has been an Associate Editor of IEEE Access, since 2019.

HUA FAN (Senior Member, IEEE) was born in Ziyang, Sichuan, China, in 1981. She received the B.S. degree in communications engineering and the M.S. degree in computer science and technology from Southwest Jiaotong University, Chengdu, China, in 2003 and 2006, respectively, and the Ph.D. degree from Tsinghua University, Beijing, in July 2013. From September 2013 to June 2016, she was an Assistant Professor with the University of Electronic Science and Technology of China, Chengdu, where she has been an Associate Professor since July 2016. From March 2015 to March 2016, she held a postdoctoral position with the Integrated Microsystem (IMS) Research Group, Department of Electrical Computer and Biomedical Engineering, University of Pavia, Italy, under the supervision of Prof. Franco Maloberti. She has authored more than 50 articles in peer reviewed journals (e.g., the IEEE Transactions on Circuits and Systems—I, the IEEE Transactions on Circuits and Systems—II, and IEEE Access) and in international conferences. Her research interests include low-power, high-speed, and high-resolution A/D converter designs. She was a recipient of a number of awards including the Best Oral Presentation Award from China Scholarship Council (CSC) support in 2015 and the IEEE Asia Pacific Conference on Circuit and Systems (APCCAS) in 2018.

MIGUEL ÁNGEL CONDE GONZÁLEZ received the Ph.D. degree in computer science from the University of Salamanca, in 2012. From 2002 to 2004, he was working in educational environment teaching in several courses related to computers. In 2004, he decided to begin working on software development environments and worked for GPM, a web development, and multimedia company. In 2005, he was with the R&D Department, Clay Formación Internacional, where he was involved in different eLearning projects. From 2010 to 2012, he was researching with the University of Salamanca, where he was also a Teacher. Since 2013, he has been with the Informatics and Communications Service, University of León, where he has been an Assistant Lecturer and is currently an Assistant Professor. He is also a member of the Robotics Research Group, University of León, and also with the GRIAL Research Group, University of Salamanca. His Ph.D. thesis focused on the merging of informal, non-formal, and formal environments. He has published more than 100 articles on different topics such as eLearning, service oriented architectures, learning analytics, mobile learning, human–computer interaction, and educational robotics.