

Article

Behavior of Science and Engineering Students to Digital Reading: Educational Disruption and Beyond

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Abstract: This paper investigates the impact of digital reading during educational disruption on science and engineering students' learning experience. Before the pandemic, some studies explored whether university students preferred using printed or digital resources for their academic readings. Amidst the pandemic, online learning became essential. Several studies showed students' preference for printed text. This paper extends a pilot study that was conducted during the first COVID-19 wave in China. A survey consisting of Likert questions and open questions was designed using MS-Forms. The survey was shared with the science and engineering students in Years 2–4 (Levels 1–3) of their study at SWJTU-Leeds Joint School, Southwest Jiaotong University in Chengdu, China. This covered students from four undergraduate programs: Civil Engineering with Transport, Electronic and Electrical Engineering, Mechanical Engineering, and Computer Science. In total, 223 students participated in this study. The survey was anonymous and was made available to students for a month. The participation rate is nearly 27%. Findings indicate that the behavior of science and engineering students toward digital reading was different than other majors, and it is generally favorable. The necessity for online learning during educational disruption has encouraged some students to develop their digital reading skills.

Keywords: digital reading; educational disruption; science and engineering education



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1. Introduction

The behavior of Higher Education students toward reading formats has been an intriguing topic for researchers for several years [1,2]. Most studies have shown that Higher Education students do not favor digital reading formats [3,4]. Recently online education suddenly became a must due to the COVID-19 pandemic [5,6]. Most universities worldwide did not have any framework for online or hybrid teaching. Accordingly, all the educators and students during the pandemic started using the 'best-we-can' strategy for learning. Some issues, such as student engagement and the impact on classroom attendance, were carefully considered when hybrid learning was used during educational disruption [7,8]. The educational disruption also led to the intensive use of digital reading materials by educators and students in a remote teaching and learning environment [9,10]. Students had to use what was available for them as digital reading devices. Some students had their digital reading and notetaking skills already developed before the pandemic, while others did not.

To the best of the authors' knowledge, no studies have focused on the attitude of science and engineering students toward digital reading. Students in the field of science and engineering may have a similar or different attitude to digital reading than students in other majors. Investigating this attitude could help develop pedagogies and future policies for digital transformation in Higher Education. Amidst the first wave of the pandemic

in China, the first author of this paper conducted a pilot study investigating engineering students' attitudes to digital reading when it was the only option for students in a remote learning environment [10]. The study showed that the reading behavior of engineering students became more e-centric due to online learning. However, the results of the pilot study could not give a conclusive view of engineering students' attitudes toward digital reading. That was because the number of participants in that study was relatively low, and they were all from one major and in the same year of study, which made the population homogenous. Earlier studies before the pandemic have shown student preference for reading in print for deep learning [11,12]. The other studies published during the pandemic reinforced the previous conclusion about unfavorable student attitudes toward digital reading [3].

Therefore, the main aim of this paper is to investigate the attitude of science and engineering students toward digital reading and find the potential reasons why some students adapted to digital reading for deep learning while others struggled or felt uncomfortable during the educational disruption period(s). The study presented in this paper reports the responses of 223 students who have studied at the University of Leeds' in China. Students from four different undergraduate programs delivered in the SWJTU-Leeds Joint School, Southwest Jiaotong University, were surveyed online following an educational disruption due to the COVID-19 pandemic. The population included students in years 2–4 (Levels 1–3) from Civil Engineering with Transport, Electronic and Electrical Engineering, Mechanical Engineering, and Computer Science. The population is thought non-homogenous enough to cover a wide range of science and engineering undergraduate education. The study is divided into four directions, including one direction focusing on the impact of the educational disruption, to address the following research questions:

- What is the potential impact on the reading behavior of the participants due to their years of study?
- To what extent has the extensive exposure to online learning impacted the reading strategy of science and engineering students?
- How likely would science and engineering undergraduate students use digital reading in the future?

In this paper, academic reading is assumed to be reading a learning material for educational purposes. This includes a textbook, lecture notes, research papers, and other readings for formative and summative assignments. Digital academic reading is defined as any academic reading on any electronic reading device. This includes digitized academic reading materials which were offered in print. Academic reading in print format includes the materials available to students as printed text or when they have access to print a given academic text in digital format.

2. Literature Review

Over the past three decades, researchers investigated electronic book usage at academic libraries. Viewing and searching electronic books has increased over the years [13].

Literature indicated that users had expressed high regard for the manifold advantages offered by electronic books. Among these benefits is the convenience of access at any given time, the ability to search through texts, the possibility of translations, sharing and manipulating text through cutting and pasting, staying updated with current information, saving physical space, the mobility to carry numerous books with ease, quick access to online references, and the environmentally friendly nature of the electronic book [14]. Two major online reading skills and content acquisition theories are Information Foraging Theory (IFT) and hypertext theory [15]. IFT describes a person's behavior while reading online and assumes that people are biologically rational and that their information-seeking mechanisms and strategies adapt to the structure of their information environment [16]. Hypertext theory refers to a text composed of blocks of words or images linked electronically, which allows readers greater autonomy and input into the text [17]. To read content, one needs to possess certain skills and tools to find, open, and control different resources, analyze

and assess digital text and interact with the content while reading. Readers must acquire distinctive methods to use digital tools effectively [18].

Students' attitudes and behavior toward digital reading became an interesting topic. A study reviewed a comparison between paper and screen reading and concluded that screen reading performance is negative [19]. Another study used a survey completed by 6005 students and focus group data in 6 high schools in Singapore to examine teenagers' reading habits in both digital and print formats. The results showed teenagers' preference for the printed format and old age moving toward digital reading [20]. A worldwide study analyzed university students' behavior and preference for reading formats. The study surveyed 10,293 students in 21 countries. The study showed that most university students prefer academic reading in print [2]. Later, the comprehensive research, which included 21,266 in 33 countries, confirmed that university students prefer printed format reading [21]. The same study also found a correlation between students' age and reading format preference. The study reported that younger students prefer printed reading formats. A qualitative analysis of students' comments published in [22] showed that their behavior is flexible. It depends on reasons such as convenience, length, and the importance of their assignments, but generally, students learn better when using a printed format.

2.1. Book Format vs. Deep Learning

Although a noticeable move from using printed reading to e-reading in Higher Education is often reported in the literature, recent research indicates that printed reading may enhance deep learning and providing students with printed materials is still very valuable [23]. It is, however, very difficult to draw clear conclusions on the role of reading format on the effectiveness of deep learning because many different factors affect it, e.g., education level and age of learners, text length and genre, type of digital device, or reading time frame [24,25]. Since the text genre was reported as one of the influencing factors of deep learning, it is possible that the effect of reading format on science and engineering students is different from that of students from different majors. More research is needed to investigate the effect of student majors on deep learning and student engagement.

2.2. Reading Format vs. Student Engagement

It is worth noting that different definitions of reading engagement can be found in the literature. For example, some authors relate it to the state of concentration [26], while others focused on the interaction between the motivation and strategies of students [27] or on reading time, reading quantity and reading interest [28]. In a recent study, conducted on 1155 university students in Anhui Province in China [29], the time and energy input by university students was used as a measure of reading engagement. The study suggested that the reading time of printed materials has a positive impact on developing the professional skills of students while the reading time of digital resources has no obvious effect because many students use digital books for recreational reading. Furthermore, digital reading may often be fragmented and difficult to adapt as a systematic knowledge-gaining strategy.

Moving quickly toward technology-driven teaching and learning during the pandemic has led to a long jump to digital transformation [30]. Numerous studies have been conducted to investigate the approach taken to online teaching and learning in Higher Education worldwide during the COVID-19 pandemic, which has subsequently led to multiple literature reviews. A review of 47 studies revealed that switching from traditional in-person learning to online education has adversely impacted students and academia [31]. The study indicated that factors such as prolonged screen time, lack of personal interaction, and dependence on pre-recorded lectures negatively affected students' mental well-being and engagement. However, the authors argue that the transition has led to innovative teaching approaches, the incorporation of modern technology, and reduced education costs. In another review, 134 research studies published between 2000 and 2020 were analyzed [32]. These studies focused on online teaching and learning methods in teacher education, explicitly examining social, cognitive, and instructional presence within the CoI

framework. While some of the studies did not directly relate to COVID-19, the authors evaluated the applicability of their findings to the current pandemic.

There are several studies that investigated the impact on academic reading due to the COVID pandemic. A study compared the effect of using print and digital reading formats on undergraduates' exam performance. The findings showed that the printed format led to higher performance by 12.65% and retention of 7.37% over the digital format [33]. The study recommended that university libraries not force digital reading for at least textbooks. A survey conducted among 318 undergraduate students from eight universities in Indonesia aimed to explore their reading behaviors and preferences in the midst of the COVID-19 pandemic. The study specifically delved into the students' motivation and favored format for academic reading materials. According to the findings, most participants still opted for the traditional print format over other alternatives [4]. By examining the effects of altered teaching delivery on students' reading habits and preferences during the pandemic, researchers were able to produce comparable results in a study that surveyed 234 UCLA students [3]. While some respondents did report improved attitudes towards digital reading during COVID-19, most attitudes were less favorable or reflected no change. Nearly half of the respondents stated that they highlighted and annotated their readings less than they did before, and over a third said they completed their assigned readings less frequently. Another study investigated how the pandemic altered the way foreign language learners read online [34]. The study surveyed 112 students using qualitative and quantitative data collection. Findings revealed four reading strategies: global, problem-solving, supportive, and socio-affective. Age and gender did not affect choices, but motivation did, impacting 13.65% of academic reading strategies. Intrinsic or extrinsic motivation also affected strategy use. A major improvement in reading habits was reported by a case study exploring the impact of the lockdown on 416 Nigerian students [35]. On average, the time spent on reading has increased from two hours a day before the pandemic to four hours a day during the lockdown. The study revealed that participants did not read for pleasure but to kill time and used a mobile phone to read. Moreover, both intrinsic and extrinsic motivations influenced the purpose of digital reading according to a study on school students in Nigeria [36]. However, overall, the study indicated improvement of digital reading habits during lockdown that can be further developed in the future. Another study investigated the internal and external factors impacting digital academic reading for 239 university students [37]. According to the results, the habit was found to be a significant determinant of reading behavior, alongside other factors. To enhance the students' digital reading endeavors, the study suggested optimizing the university's digital library and resources to elevate students' expectations.

The impact of COVID-19 on specifically engineering students' digital reading was reported by two studies conducted at the University of Nottingham Ningbo China (UNNC). The first study was in response to the first wave of COVID-19 in China, to survey the attitudes of final-year engineering students towards digital reading as remote learning disrupted traditional learning [10]. The survey was based on a specific study of the reading preferences of UCLA students and another widespread international study of university students. According to the findings, engineering students do not exhibit a particular affinity for reading material. Instead, they tend to convert their physical reading materials into digital formats and may print digital readings based on their preferences. Most respondents acknowledged that they had altered their reading habits in response to the pandemic's impact on the learning environment. Another UNNC study investigated engineering students' attitudes toward digital reading devices in the post-pandemic era [9]. Results indicate that engineering students have specific device preferences for digital reading, favoring those that aid diverse research, including reading, writing, and searching for information. Furthermore, students prefer utilizing both physical and digital texts, engaging in an interconnected process of reading, writing, and finding information across multiple devices. While digital readers are beneficial for focused reading, students reported

multitasking by reading, writing, and searching simultaneously, indicating the importance of versatile device capabilities.

Digital reading was considered more affordable and economical than printed reading in the early days. However, nowadays, though still economical, the price of new and popular eBooks is much closer to printed books. A recent survey in the U.S. showed that 37% of adults read printed books compared to 7% who said they only read eBooks, and 28% read in both formats [38]. The findings of the same survey showed that eBook sales increased by 22% in 2020; even though the ratio of outselling printed to eBooks is 4 to 1.

2.3. Reading for Engineering Students

Most of the literature investigating university students' reading habits focuses on humanities, social sciences, or general education courses [39,40]. However, the reading behavior of university students may be related to the subject areas they study [41]. For instance, science and engineering students may have different approaches and strategies than university students in other majors, as they sometimes read for other purposes, such as research and writing up scientific or engineering reports [9]. An earlier study assessing what engineering students learned during the design process found that first-year students who read an engineering textbook spent significantly longer time but at better quality to solve an open-ended engineering problem than those who tried to solve the problem before reading [42]. Researchers conducted a student survey at the ORT Braude Academic College for Engineering in Israel and found that many engineering students did not read printed textbooks very often even though they felt that textbooks were an important component of the university's learning environment [43]. More recently, Ref. [44] reported that the effectiveness of reading amongst diploma engineering students is significantly affected by their critical reading skills and university educators should support the students to develop their critical reading skills and strategies. There is also no conclusive evidence in the literature on the effect of reading format on engineering students' learning. For example, based on a pilot study conducted on 50 undergraduate students at NED University in Pakistan, Ref. [45] reported that most students preferred reading printed materials and they believed that reading help them enhance their creative skills. However, Ref. [46] carried out a survey on reading habits among agriculture and engineering undergraduates of a university in Nigeria, which showed that students read mostly lecture notes and textbooks to pass their examinations. The agriculture and engineering students' reading habits were significantly affected by social networking and very busy academic timetables. Further research is, therefore, needed to understand the reading habits of science and engineering students.

2.4. Future Academic Reading Format

The literature is generally conclusive on the future of the academic reading format. Regardless of the above-mentioned benefits and limitations of digital reading, it is clear that digital reading cannot be avoided, both in our daily life and in the Higher Education sector (e.g., [23,29,47–49]). As pointed out above, this does not mean that printed materials are not important, and university libraries should stop investing in printed academic materials. Perhaps the most reasonable approach is to develop policies and practices promoting hybrid reading in which printed and digital reading complement each other (e.g., [29,48,50]). However, the reading behavior of students, including those in science and engineering, needs to be better understood so that library directors and university policymakers invest their resources appropriately to enhance student learning.

The aim of this study is to develop a better understanding of science engineering students' reading habits and investigate further their perception of the impact that digital and printed academic reading may have on their learning and academic success. The study presented in this paper reports the responses of 223 students who have studied for the University of Leeds' degrees in SWJTU-Leeds Joint School, Chengdu, China. The population included undergraduate science and engineering students in years 2–4 (Levels 1–3). By

November 2022, when this study was conducted, year 2 participants had spent at least three academic semesters using digital reading. Year 3 and year 4 students had more extended experience with e-learning and digital reading in 5 and 7 academic semesters, respectively.

3. Methodology

This study extends an initial pilot study conducted at UNNC early in 2020 in response to the first COVID-19 outbreak in China [10]. The initial pilot study used a survey, based on a study at UCLA that investigated the attitude of undergraduate students toward reading format preferences and an international study among many universities worldwide [2]. The study presented in this paper uses a survey with similar questions to the initial pilot study [1] divided into four themes. Format preference for academic reading, learning engagement, language influence, and the impact of the educational disruption on reading behavior.

The survey consisted of eight Likert-style statements, most of which used a 5-point scale: strongly agree, agree, neutral, disagree, and strongly disagree. Twelve open questions were used to comment on student choices. Among the 23 survey questions, additional questions adapted from [3] were added to the present study to investigate students' preference for digital reading and reading in print and students' engagement when using a different format and reading devices.

The study was conducted under the University of Leeds Research Ethics Policy for research involving living human participants and their personal data. A research ethics application form was submitted to the Faculty of Engineering and Physical Sciences Research Ethics Committee and approved. The application included a proportionate ethical short review form, consent form, and information sheet for the participants. All the participants were informed that the survey was anonymous; therefore, no incentives were given to the participants. This also ensured no disadvantage for the participants or other students who did not complete the survey.

The survey was distributed to undergraduate students from years 2, 3, and 4 of study at SWJTU-Leeds Joint School, Southwest Jiaotong University in Chengdu, China. The survey was made available online through MS-Forms. The survey was shared with 839 students from four programs of study: BEng Electronic and Electrical Engineering, BEng Civil Engineering with Transport, BEng Mechanical Engineering, and BSc Computer Science. Students were invited to complete the survey via a general email to all undergraduate students with a few reminders. The survey was available for students to complete for a month in November 2022. Two hundred twenty-three students completed the survey voluntarily, with a participation rate of nearly 27%. The researchers assumed this participation rate was satisfactory, considering no incentives. Excel and SSPS were used to analyze the responses. Thematic analyses were used for the open questions fields to derive meaning from the results.

In terms of gender, the responses are divided as 23% female ($n = 52$), 73% male ($n = 162$), and 4% ($n = 9$) prefer not to say. Among the participants, 32% ($n = 72$) belong to Civil Engineering with Transport, 25% ($n = 56$) to Electronic and Electrical Engineering, 22% ($n = 48$) to Computer Science, and 21% ($n = 47$) to Mechanical Engineering. In terms of the year of study, the majority of the participants (40%, $n = 89$) were from year 2. Year 4 participants were slightly lower (36%, $n = 80$). The contribution from year 3 was the lowest (24%, $n = 54$). The distribution by the program of study and the breakdown by the year of study is illustrated in Figure 1.

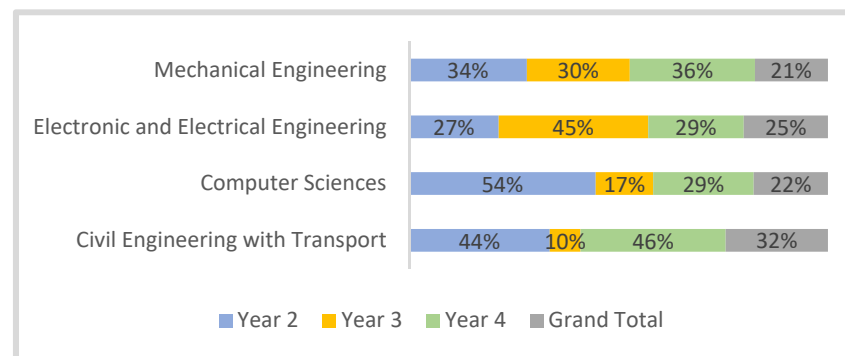


Figure 1. Distribution of participants by program and year of study.

4. Results

In this section, the responses are presented according to the four themes of the survey. Likert-style questions were arranged on a 5-point scale, but the responses ‘strongly agree/agree’ and ‘strongly disagree/disagree’ were combined for clarity. The responses are illustrated based on the year of study.

4.1. Format Preference for Academic Reading

Students were asked to what extent they agree if reading their academic material in print can help them to remember, and the results are illustrated in Figure 2.

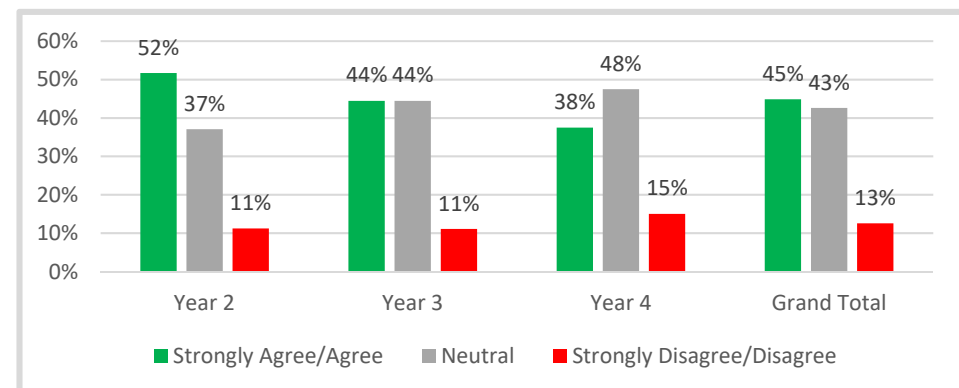


Figure 2. Print format preference for remembering information.

In total, 13% of the participants disagree or strongly disagree with the statement, 45% strongly agree or disagree, and 43% neutral. The same percentage of participants, 11% from year 2 and year 3 disagree or strongly disagree, while the percentage is slightly higher (15%) in year 4. It also turns out from Figure 2 that the highest percentage (52%) of those who agree to a certain extent belong to year 2, followed by year 3 (44%), then year 4 (38%). When comparing these responses with those published in the worldwide study before the pandemic [2], an apparent drop was noticed in those who agreed to a certain extent among engineering student participants in the current study against 63.4% of Chinese students and 72.3% worldwide in [2] (p. 14). The percentage of the participants who strongly disagree or disagree that they remember better when they read in print also increased from 8.1% among Chinese students and 11.2% worldwide before the pandemic to 13%, as shown in Figure 2.

The responses to whether it is more convenient for students to read their assigned academic readings in digital format are illustrated in Figure 3. In total, 50% of the participants strongly agree or agree, while 20% disagree to a certain extent. It is also noticed that more participants from year 4 strongly agree or agree with the statement. The results seem consistent with those of the previous question in Figure 2; the more senior the students are,

the less they strongly disagree or disagree about the convenience of digital reading. These results are consistent with those published in [21].

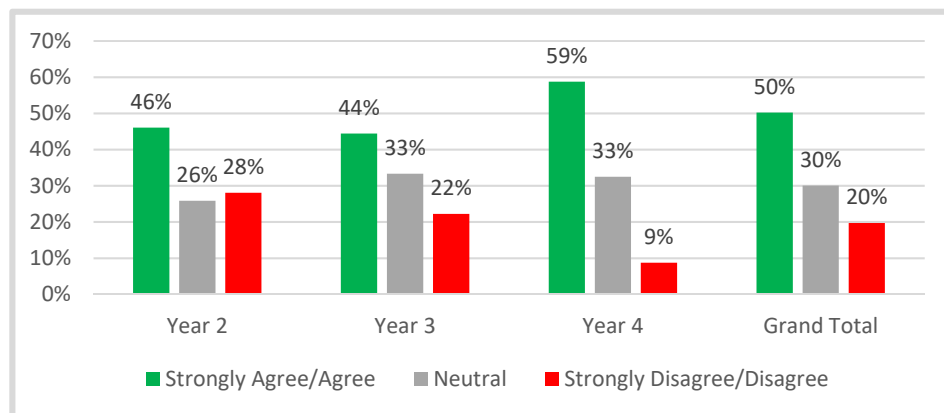


Figure 3. Digital format preference for convenience.

Figure 4 illustrates the responses to whether the participants prefer having all their academic readings in printed format. In total, 36% of the respondents agree to a certain extent, while 26% strongly disagree or disagree. In comparison with the worldwide study, we noticed the flexibility of engineering students who participated in this study as it was reported before the pandemic that 64.97% of the students worldwide and 80.1% of the Chinese students strongly agree or agree, and 19.97% of the students worldwide and 6.8% of the Chinese students disagree to a certain extent [2] (pp. 16–17). It is also apparent that more participants in year 4 responded they were neutral. Again, the more senior the students are, the less they strongly agree or agree they prefer to have all their academic readings in print.

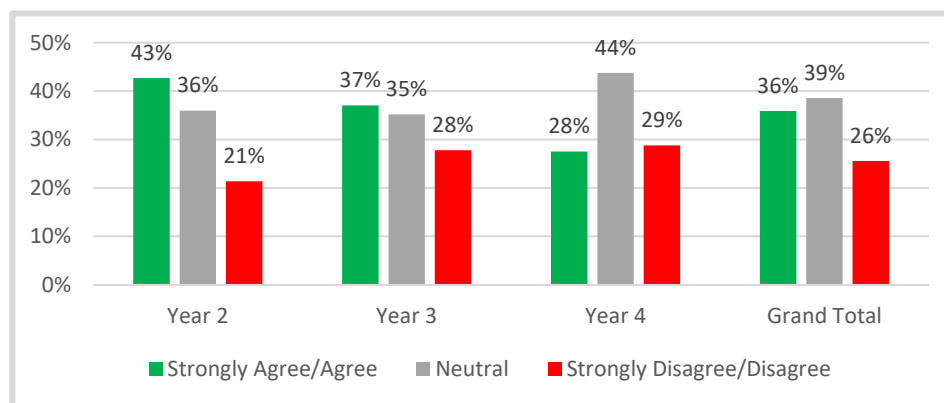


Figure 4. Print reading format preferences.

The participants were asked if they preferred printed format for reading assignments longer than seven pages and digital format for readings shorter than seven pages. The responses to these two statements are illustrated in Figures 5 and 6, respectively. In total, 49% of the participants strongly agree or agree they prefer the printed format for long readings, against 26% strongly disagree or disagree [51]. Compared to the results reported before the pandemic, the change is evident in favor of digital reading, as 72.83% worldwide and 78.3% of the participants from China strongly agreed or agreed. In comparison, 15.54% worldwide and 9% of the participants from China disagreed somewhat [2] (pp. 20–21).

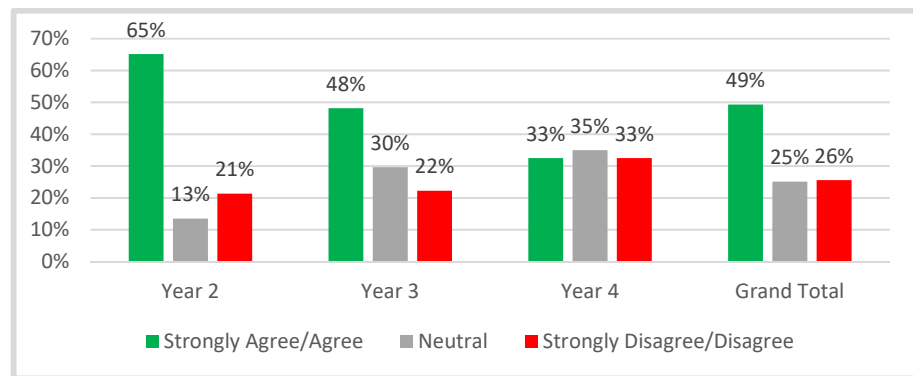


Figure 5. Preference of printed format for more than seven pages.

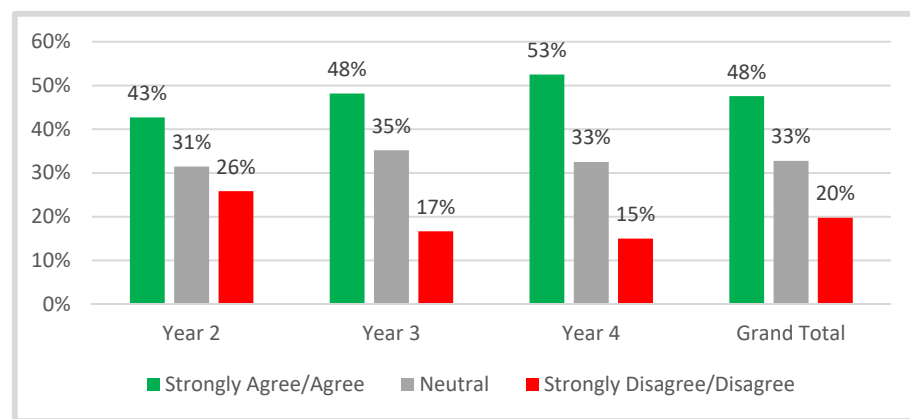


Figure 6. Preference of digital format for less than 7 pages.

Figure 7 illustrates participant responses to whether they prefer digital reading over printed reading. 32% of the participants from all years of their study responded they strongly agree or agree with the statement, while the same percentage disagree to a certain extent. It is noticed that the percentage of those who felt neutral is almost constant at ~36%. As per Figure 7, while the percentage of those who strongly agree or agree remains nearly the same (24–25%) in years 2 and 3, the percentage increased significantly (45%) among year 4 participants. The results presented in Figure 7 suggest that students’ preference for digital reading over printed format may be related to the year of study. This could explain how the percentage of those who disagree to a certain extent drops from 40% to 39% in year 2 and year 3 to 19% in year 4. However, more data and detailed analysis are required to verify this suggestion.

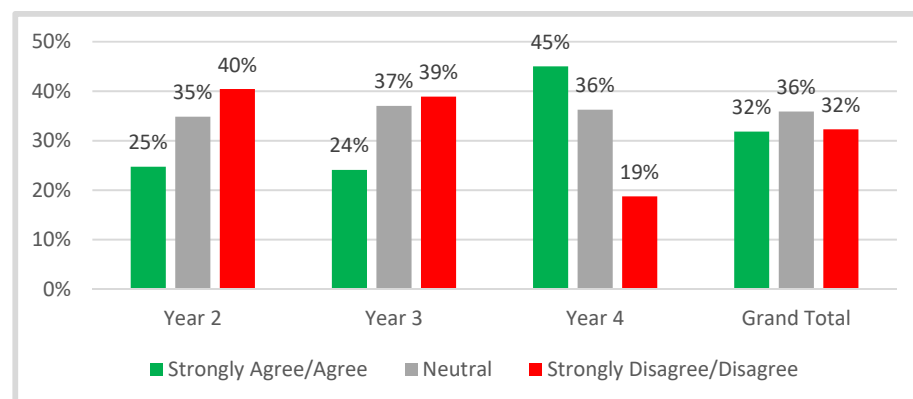


Figure 7. Preference for digital reading over printed reading material.

Figure 8 illustrates the responses to what extent the participants agree that reading in printed format can help them to focus better. Overall, 57% of the participants strongly agree or agree, compared to 82.02% among students worldwide and 80.4% among Chinese students [2] (pp. 14–15); 13% of engineering students strongly disagreed or disagreed with the statement, which is almost double the percentage of 7.45% among students worldwide [2] and significantly higher compared to the Chinese students (5%). Moreover, in Figure 8, the percentage of those who strongly disagree or agree almost doubled (19%) in year 4 compared to year 2 and year 3 (9%).

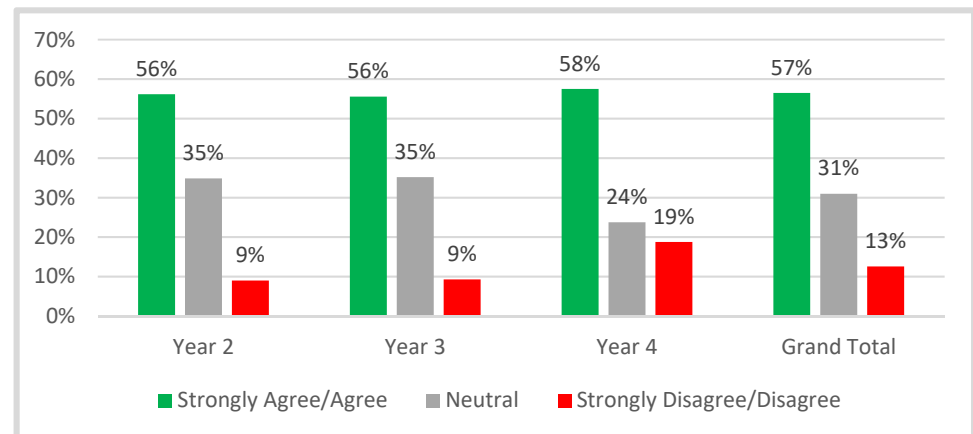


Figure 8. Preference of print format for deep reading.

The next question was if the participants prefer to read their academic reading electronically, and the responses are illustrated in Figure 9. It turns out from the percentage of those who strongly agree or agree that senior students in year 4 (46%) are more open to digital reading for their academic reading than students in year 2 (27%) and year 3 (26%). The percentage of those who do not prefer academic reading digitally dropped by more than half (15%) in year 4 compared to that (33%) of year 2 and year 3 participants. Those percentages reflect how the reading strategy of engineering students' participants in the current study has changed compared to those reported before the pandemic. As in [2], only 12.82% of the students worldwide and 13.6% of Chinese students preferred digital format for academic reading (pp. 18–19).

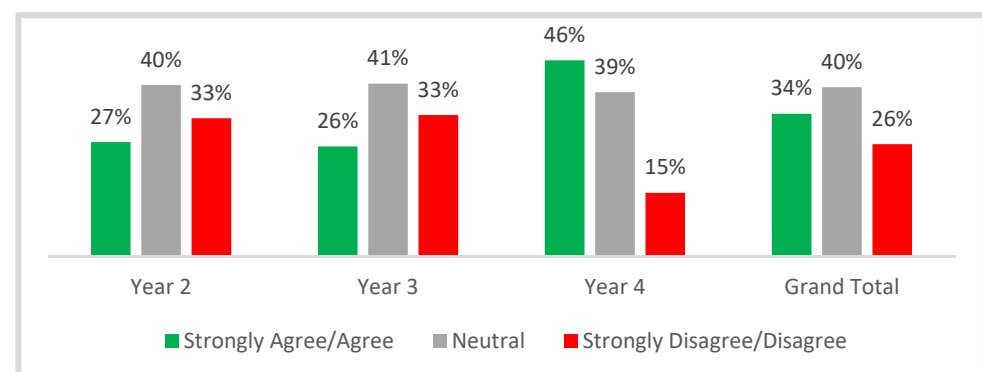


Figure 9. Preference of doing academic reading electronically.

There were six media preferred for digital reading according to the participants' responses illustrated in Figure 10. An iPad and a laptop were the most preferred, 26% each; 18% preferred other tablets. Other media preferences included specific e-readers 9%, smartphones 8%, and desktop computers 8%. None of the participants mentioned audiobooks; 5% of the participants did not show a preference for any digital reading media, as they insisted on conducting their academic readings in printed format. This percentage is consistent with that reported in [2], as 4.34% of the worldwide participants did not prefer

any device for e-reading (p. 10). However, although the laptop was the most preferred by 80.9% before the pandemic, we can see a drop in engineering students' preferences in this study. Using the smartphone is also impractical for engineering students as it dropped from 36.83% in [2] to 8% in this study. It is also noticed that tablets and iPads are more preferred for engineering students as their preference increased from 28.43% in [2] to 44% in this study. E-readers slightly increased from 7% to 9%. Desktop computers also became less preferable as the percentage dropped from 30.54% to 8% in this study, which is expected as mobile learning technologies advance rapidly.

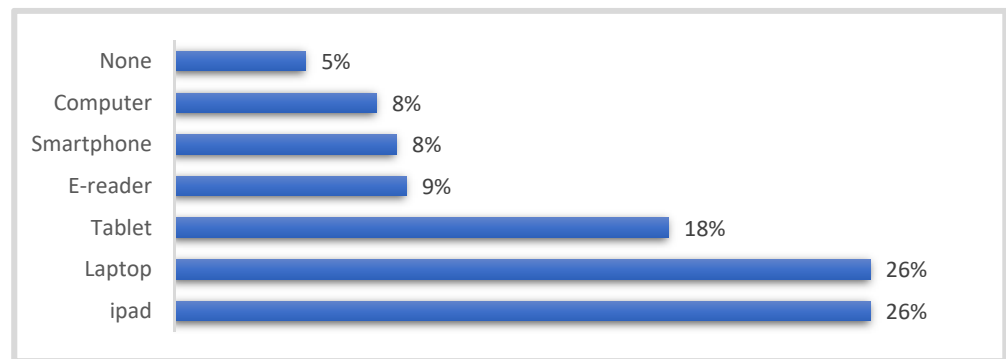


Figure 10. Preference of digital reading medium for academic readings.

4.2. Learning Engagement

The second theme of this study investigates the participants' learning engagement with their academic readings in both printed and digital formats. The participants were asked to show their responses and whether they usually highlight and annotate their printed academic readings. As demonstrated in Figure 11, overall, 65% of the engineering student participants highlight or annotate their printed material for effective learning compared to 83.6% in [2]. These results show less engagement of engineering students with their printed readings than general university students. Similarly, the participants were asked to respond to whether they usually highlight or annotate their digital academic readings, as illustrated in Figure 12. Overall, 61% of the participants strongly agree or agree. This shows slightly less engagement compared to printed readings in Figure 11. A significant difference can be noticed when the responses in this study are compared to those published in [2]. Only 24.11% said they strongly agree or agree they usually highlight or annotate their electronic readings (p. 13). When the results were compared with those published after the pandemic, a significantly higher level of engagement was noticed among engineering students than among general university students. Only 11% in [3] said they have higher engagement behaviors with their readings through the pandemic (p. 6).

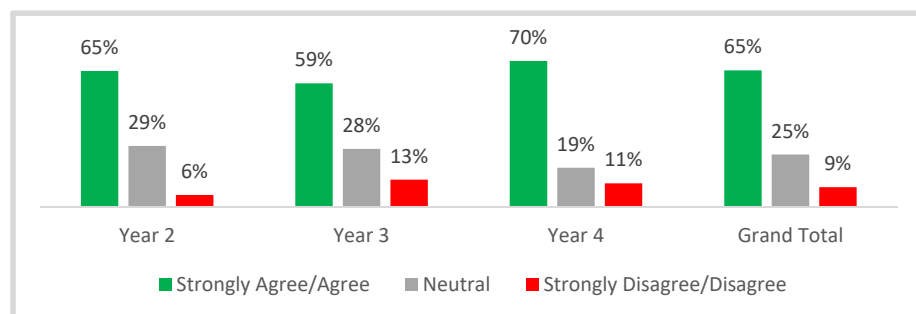


Figure 11. Highlighting and annotating printed academic readings.

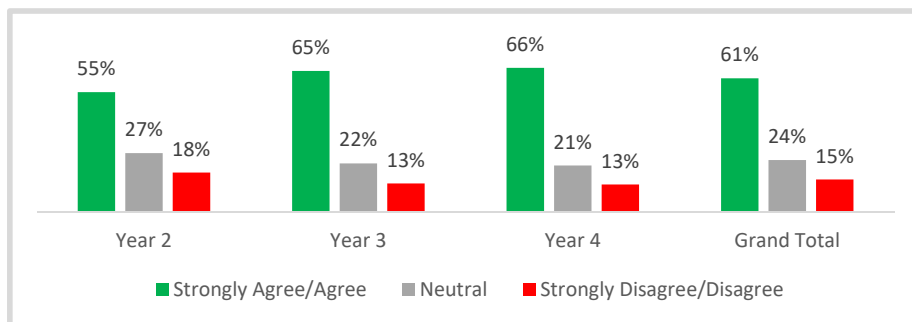


Figure 12. Highlighting and annotating digital academic readings.

Figure 13 illustrates the participants’ responses to whether they are more likely to review their printed academic readings. Overall, 48% of the participants strongly agreed or agreed; 17% disagreed to a certain extent, with the largest percentage among year 4 students.

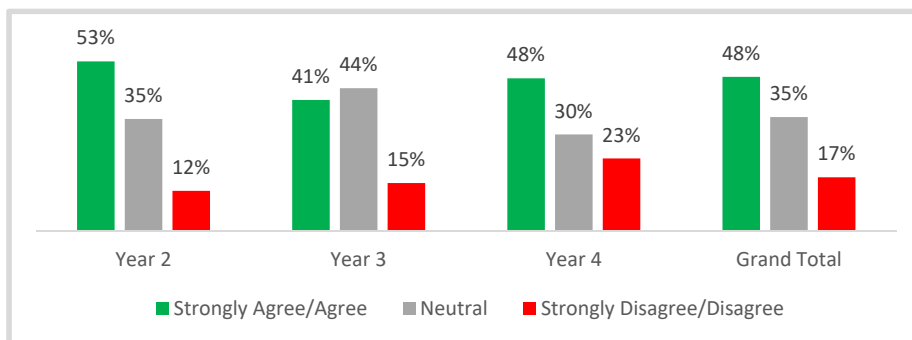


Figure 13. Likelihood of reviewing printed academic reading.

Figure 14 illustrates the participant responses to whether they prefer printing their academic reading material rather than reading it electronically. Overall, 39% of the participants strongly agreed or agreed, while 23% disagreed to a certain extent. Compared to the published results in [2], more than 68.85% (worldwide) and 78% (Chinese) strongly agreed or agreed, and only 13.15% (worldwide) and 8.4% (Chinese) strongly disagreed or disagreed. This reflects a great change in engineering students’ reading strategy compared with other students in Higher Education.

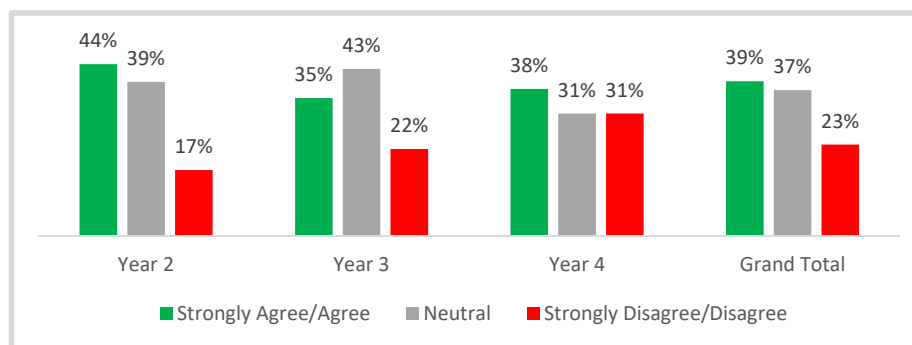


Figure 14. Preference for printing digital academic readings.

When the participants were asked whether they like to make digital copies of their academic material in print, 43% responded they strongly agree or agree, and 21% disagree to a certain extent, as shown in Figure 15. It is noticed that more senior students are keen on digitizing their printed academic reading materials. We could not compare the results of this question with [2] as it was dropped in the original study due to inconsistency.

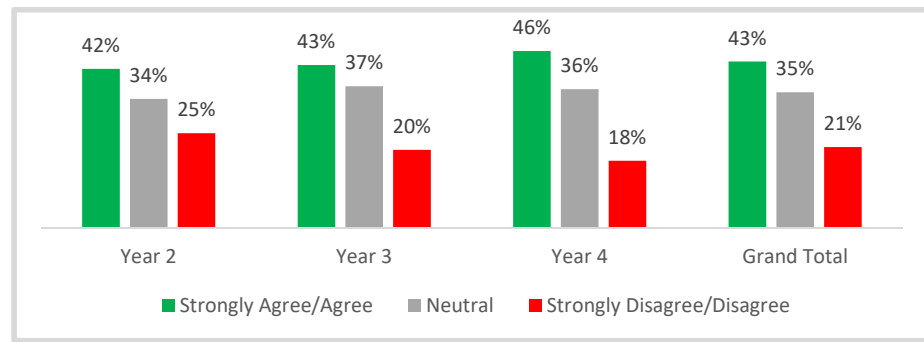


Figure 15. Preference of digitizing the printed academic reading.

4.3. Language Influence

Figures 16 and 17 show the participants’ responses to what extent they prefer reading their native language academic material in printed and digital formats, respectively. Overall, 45% of the participants agree to some extent they prefer printed format for the material available in their native language, while 17 strongly disagree or disagree. Figure 16 also indicates that more senior students do not prefer printed format compared to students in year 2 and year 3. Figure 17 shows that fewer students prefer using the printed format for their academic readings provided in a foreign language. This becomes even more obvious when we compare the responses in Figures 16 and 17, year after year. More senior students disagree to some extent with using the printed format for their academic reading provided in a foreign language. Figure 18 illustrates to what extent the engineering students who participated in this study agree that their preferred reading format depends on the language of the academic reading material. Overall, 35% of the participants agree to some extent, while 28% strongly disagree or disagree. The results show more dependence of the reading format on the language when compared with those published in [2]; 56.11% of the respondents disagreed to some extent, and only 15% strongly agree or agree (p. 16). This is probably because all the participants in the current study are non-native English speakers, and they are all enrolled in the international programs delivered in English.

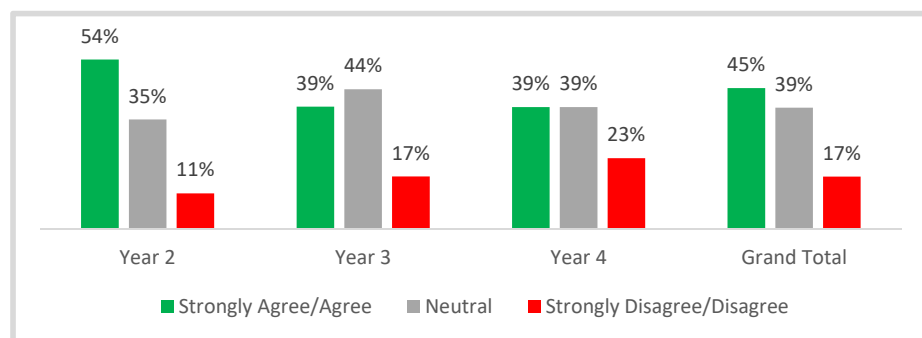


Figure 16. Preference of reading native language academic material in printed format.

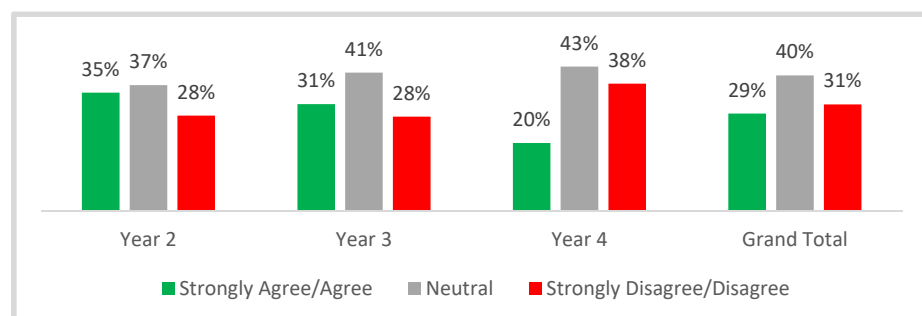


Figure 17. Preference of reading foreign language academic material in printed format.

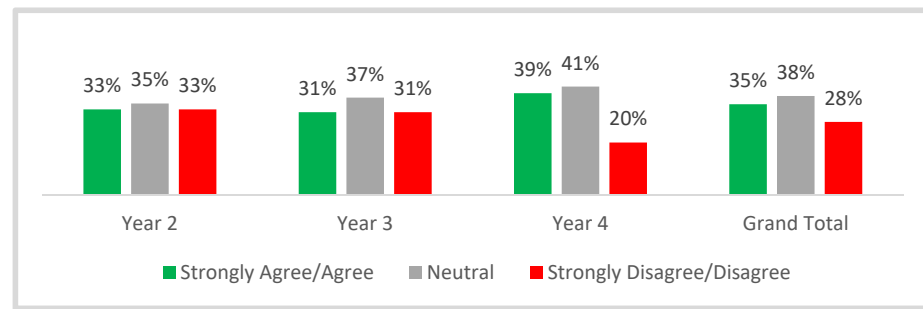


Figure 18. Dependence of academic reading format on the language.

4.4. Impact of Educational Disruption on Reading Behavior

The participants were asked how often they used digital reading during the educational disruption; the responses are illustrated in Figure 19. Overall, 73% of the students used digital reading daily for their studies; 16% of them used it at least twice a week, 10% used it occasionally, and 1% never used it. Figure 19 also indicates that senior students used digital reading more than students in year 2. It turns out that all students in year 4 have used a digital format for their academic reading. The participants mentioned that digital reading became unavoidable for e-learning. They also found it mandatory for coursework or reading for research.

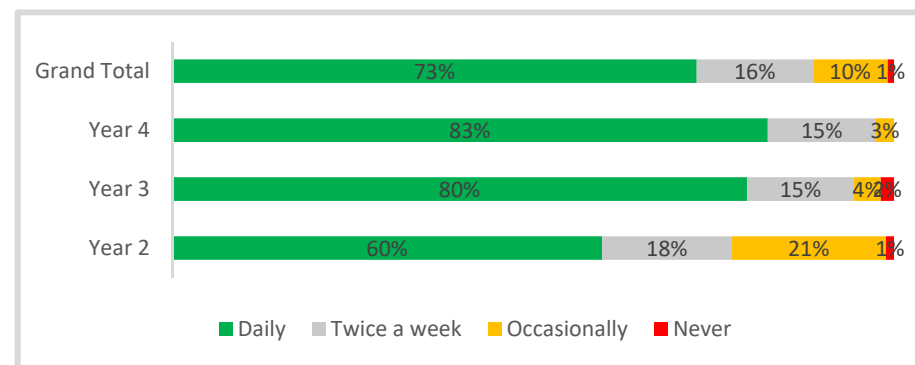


Figure 19. Frequency of using digital reading during educational disruption.

Additionally, there was no printing option for many students. Many science and engineering students have also developed their habits of using digital reading.

“I can’t avoid e-reading”, “E-reading is more suitable for online learning”, “It’s common to use e-reading when I study online”, “use e-reading during the online study benefit me. easy for me to review the materials.”

“Electronic reading makes a large amount of literature more convenient”, “There is a lot of coursework to be finished so I need to read them every day,”

“Of course, I used digital reading daily. All materials we receive are online, and I definitely cannot print all them out”, “I have to study and review by reading e materials such as ppt. Since they are too many, I cannot print all of them”

“I have been using academic e-reading for 3 years”, “I usually use e-reading in my daily life”

The participants were asked whether their reading behavior changed during educational disruption to be more e-centric, and the responses are illustrated in Figure 20. It turns out from the responses that 51% of the overall participants strongly agree or agree. The percentage is ascending per year of study, with 59% in year 4. These results are consistent with what has been reported in the preliminary study amid the pandemic [10]. The percentage of those who disagree to some extent seems to be constant (nearly 15%). The results presented in Figure 20 reflect a massive change in engineering students’ reading

strategy compared to those published in [3], with 47% who dislike digital reading more after the pandemic. The 15% group of students in Figure 20 seem to be a big fan of the printed format for the reasons discussed under the previous theme or may be reluctant to use digital reading.

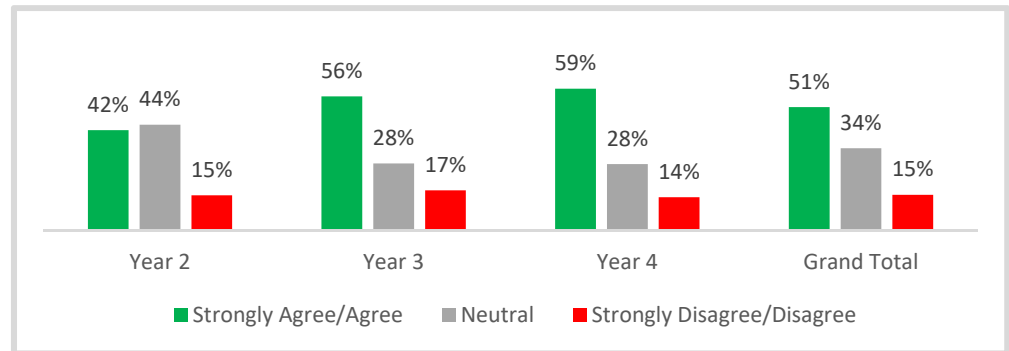


Figure 20. Change of reading behavior due to educational disruption.

The participants used a variety of resources to find the digital reading material. Figure 21 shows the possible resources. It turns out that students rely heavily on the material provided in the Virtual Learning Environment (25%), and they use the university digital library 20%. Other sources included web resources 26%, search engines 16%, and Google Scholar 13%.

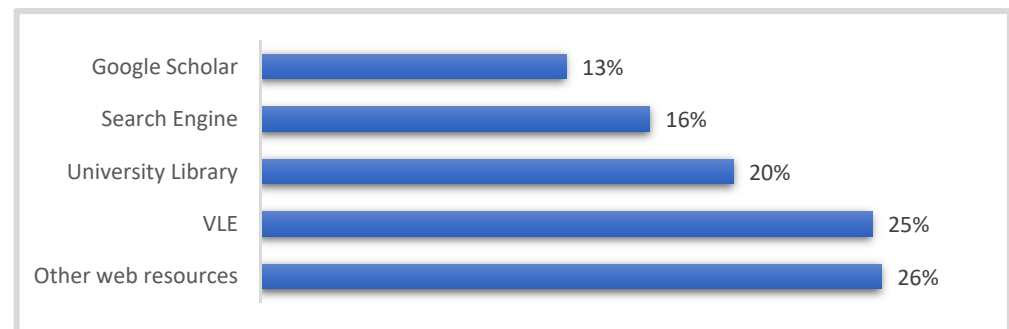


Figure 21. Resources used to obtain digital reading material.

The participants were asked whether academic digital reading during educational disruption feels worthwhile, better, or as normal as during normal study time. The responses are illustrated in Figure 22. While 36% of the participants did not mention major differences, and they felt it was pretty much the same, we were surprised to see 40% of the students feeling that digital reading was even better during the disruption.

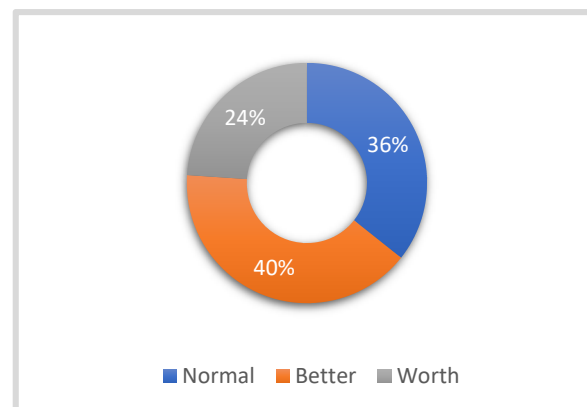


Figure 22. E-reading in lockdown compared to normal study.

To investigate the effect of the reading device on the reading performance, the participants were asked how different media caused them to feel distracted and the impact of using various media on remembering the information. The responses are illustrated in Figures 23 and 24, respectively. From Figure 23, the smartphone is the highest distracting device for digital reading, as 37% of the participants felt highly distracted, and 28% felt likely distracted using it. Computers and laptops similarly affect the participants' feeling highly distracted or likely distracted. E-reader was the minor device causing the participants to feel highly distracted (4%) or likely distracted (17%).

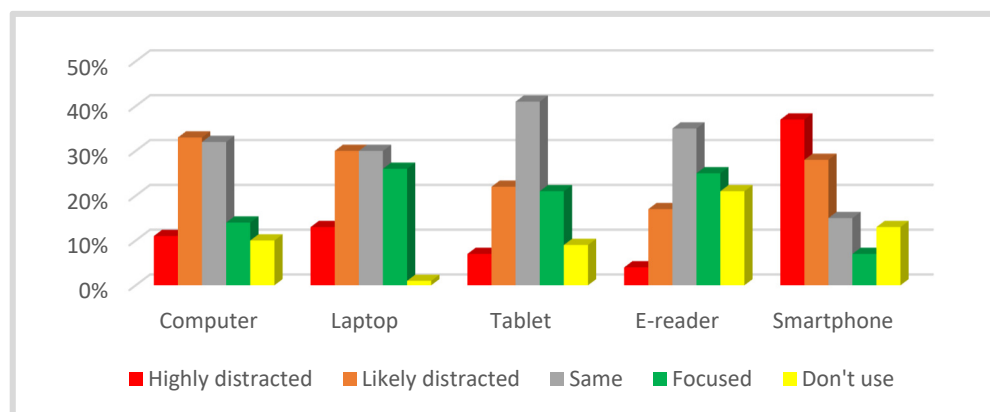


Figure 23. Effect of different reading media on student distraction.

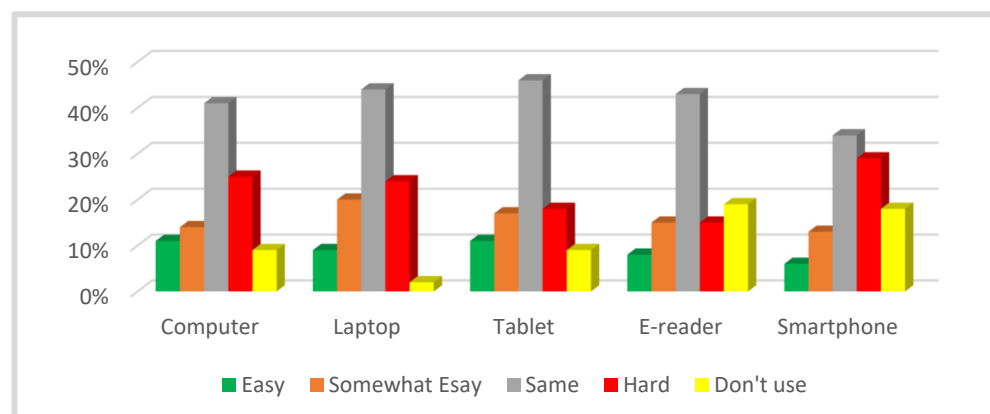


Figure 24. Effect of different reading media on remembering the information.

Regarding remembering the information, Figure 24 shows that the participants felt nearly the same as reading printed text when using tablets, laptops, and e-readers; 29% of them thought it was hard to remember when using a smartphone, 25% when using computers, followed by a laptop, 24%; 18% said they do not use a smartphone for reading, while 19% do not use e-reading, likely for its unavailability, as discussed previously.

To investigate the participants' views about the future use of digital reading, they were asked whether they continued using it after the study went back to normal and if they intend to use academic digital reading. 84% of the students said they continued using academic digital reading after the lockdown. Furthermore, almost the same percentage (83%) said they intend to continue using academic digital reading in the future. They supported their preference citing reasons such as convenience, portability, the economy of digital notetaking compared to printing, and searchability. Besides, they think that digital learning may help them improve their learning.

“It is sometimes easier to organize materials digitally. Also, some experiments are carried online, which works better with e-document”, “It is useful and convenient. It is not necessary to bring many printed papers if using e-reading”, “e-reading can help me to

take notes”, “it is more extensive, convenient and low-cost access to electronic resources”, “it wastes time to print each time”, “printing is costly and hard to reserve”, “I will continue to use it. When I read electronically, I can look up information more quickly and take notes more easily” and “I am getting familiar with this learning mode. And my learning efficiency can be improved”

5. Discussion

This study extends a pilot study conducted among students who attended a final year optional engineering module at the University of Nottingham Ningbo China, amidst the COVID-19 outbreak in early 2020. The finding of the pilot study was used to hypothesize that science and engineering students have changed their reading strategies and become more e-centric as a result of extensive exposure to online learning [10]. One-third of the participants felt digital academic reading during the educational disruption was normal compared to during the regular study time. Moreover, participants who felt academic digital reading was better during disruption were nearly double compared to those who thought it was worse. Students supported their opinion with reasons, including flexibility and using only one reading device to get their study done. Moreover, it was beneficial for some students as they think that educational disruption allowed them to experience digital reading more, develop the habit of using it in their study, and better organize their digital reading material.

Nearly a quarter of the participants did not like using digital reading during the pandemic or thought it was not as efficient as in normal study time. That is because they felt distracted, not having options for printing their material or not having digital ink to facilitate annotation and taking comments. This is because, during educational disruption, students used what was available to them as reading devices. Additionally, there was no framework for digital reading set by the universities. For example, it was interesting to see that more than one-third of the participants thought an e-reader could be the same as printed material in that it is less distracting than other digital reading devices, even though it was the highest percentage of the devices students did not use, likely due to the unavailability. Not many students will buy an extra device for reading if they buy a tablet or laptop.

5.1. Format Preference

The results of the current study are compared with those published during and after the pandemic to investigate whether students' reading strategy has changed due to educational disruption [3]. The published results after the pandemic were consistent with the previous studies, as 78.2% of the students said reading in a printed format helped them remember the information (p. 5). However, in the current study, the percentage significantly decreased (45%) among science and engineering students.

A relation between the year of study and the reading format preferences was noticed for the assigned reading length. There is a noticeable spike among year 2 participants for the printed format. This percentage decreases among the senior students, i.e., year 3 and year 4. A similar response was noticed as the percentage of the participants who said they prefer digital reading format for seven or more pages grows in the opposite direction towards the seniority of the students. A significant difference was noticed when the current findings were compared with those in [2] (p. 22); 28.76% in [2] preferred digital format for readings of length less than seven pages compared to 48% in the current study, and 40.54% disagreed to a certain extent before the pandemic compared to 20% among science and engineering participants in the current study. The changes in science and engineering students' strategy toward digital reading were confirmed in comparison with the published results as the percentage of the participants in the current study who felt it was easy to focus to some extent using printed format dropped to 57% compared to the 81.6% participants in [3] (p. 5).

The attitude towards reading format following the educational disruption has shown that science and engineering students will be in favor of academic reading in print, for its simplicity of annotating the printed text and the natural (real) reading atmosphere, which is consistent with those in [3] (p. 5). Students will also be attracted to reading in print for the ease of instant access or quickness and the ease of remembering. Unexpectedly, it was noticed that not many science and engineering students liked the printed format for long readings, and even some students do not like to use printed format anymore. Reasons such as the weight of printed materials and difficulty carrying them, not being easy to store, or likely getting damaged, and search inability is why more science and engineering students are moving towards digital reading. This can also be important when students read about a difficult subject or read in a foreign language, such as students who participated in this study. Printing costs and wasting paper are also issues that can be considered.

On the other hand, the participants liked academic digital reading for its accessibility and convenience, portability, and lightweight. Participants who developed their habits of using digital reading and have devices equipped with digital ink value digital notetaking. Flexibility and ease of storing and restoring from the cloud were extra reasons why participants considered shifting their reading strategy after they experienced digital reading for their learning during the pandemic. The academic digital reading experience on reading devices equipped with search engines and translators was very beneficial for science and engineering students. However, some participants seem reluctant to use digital reading because of their habits of reading in printed format for so many years since they started their primary education [37]. This is because of the unreal feeling and the need for digital ink or electronic pen for annotation and writing comments. Some are also concerned about causing eyestrain or bringing headaches. Surprisingly, many of the participants said there is nothing they do not like about digital reading.

5.2. Reading Engagement

It was noticed when investigating student engagement with their reading that fewer students in year 2, compared to the other years of study, said they engage with their digital readings. This reflects the reluctance of junior students to use digital reading compared to students in year 3 and year 4. These results show that science and engineering students may use reading for other purposes, such as research and writing up their reports. The results are also consistent with those published in [9] as the academic digital reading of engineering students is strongly correlated with the research process, and “engineering students rarely just read” as they “read, write, and find information”. Senior students do much of their reading for purposes like research or writing up their coursework [9]. They read from many sources and possibly do not have time to review everything they read. A lack of confidence among year 2 students, as they are relatively new to university life and may need to review more, especially if they have time for that, should also be considered. The correlation between age and print preference is consistent with those published in [21,52], as students in the first years may not feel fully immersed in the academic process and prefer to engage with the printed format for better improvement and comprehension. This can be supported, for example, by observing an ascending curve per year of study for participants who do not prefer to print their academic readings that were initially handed out in the digital format.

5.3. Language Impact

The current study results show that more senior students do not prefer printed format for native language reading. The results also show the correlation between the year of study and the preference for using the printed format for foreign language academic reading. These results were another indicator of how senior students in the final year have adapted to digital reading independently of the language, although the printed format is preferred for native language readings. The participants supported their preferences of the format with reasons such as habit, length of the reading material, and complexity rather than

the language. Their comments indicate that habit is a common factor that may influence their reading strategy. This is consistent with another study that reported print reading habits among the factors influencing the preferred reading format [4,37]. However, some participants have experienced the language influence oppositely, as they prefer using the digital reading format for their native language reading.

In contrast, students prefer printed format for foreign language readings. They explained that foreign languages might require deep reading, which is more convenient in a printed format. Some of them also feel it would be easier to take notes when reading the foreign language in a printed format, but this depends on the availability of a reading device equipped with digital ink. On the other hand, those who think the reading format is independent of the language provided reasons such as convenience, the difficulty of the content, habits, or economic reasons.

5.4. Recommendations

The outcomes of the study have potential implications for student/educator training, educational policymakers, and the design and use of educational learning technologies. Science and engineering education authorities are advised to provide pedagogical training on digital reading and its integration into student learning. Sharing experiences and good practices among different departments and levels of study are also encouraged. Students are expected to develop their pedagogical knowledge and self-efficacy in digital reading during their first two years to build digital reading habits that support their learning goals. Students have been given the option to choose the digital reading medium they prefer. Most of the academic digital reading material was provided to students in PDF format, which is suitable for many digital reading devices, including mobile phones. During educational disruption, many students independently developed their academic digital reading skills. To maintain their enthusiasm, policies should be developed to promote the necessary pedagogies for digital transformation, including a structural framework for digital reading. Extracurricular activities promoting digital reading, writing, and notetaking can be conducted in the first two academic years of Higher Education. This will help students develop their digital reading skills while making it enjoyable. Universities may also suggest using a tablet or dedicated e-readers with digital ink and a sufficiently large display, offering students a few options to instill a digital transformation culture. Digital reading skills can be developed wherever affordable and convenient tools are available, just like any other habit.

In parallel, science and engineering educators should have access to the latest digital reading tools and technologies that their students use. Educators should attend regular training sessions on digital reading media, software, apps, and pedagogical practices to share best practices and innovative use of digital reading tools in teaching and research activities.

Libraries may start focusing on having a few hard copies of fundamental science textbooks used in the first two years of Higher Education, as senior science and engineering students may read more for research and writing purposes. Other textbooks and journals covering more complex topics could be made available in digital format. If digital transformation had to be implemented fully, it could start from the final year downwards. Teaching and learning authorities in Higher Education should ensure that all students have access to digital reading materials. Reducing the cost of library buildings and bookshelves for printed materials could free up funds to invest in digital reading devices and training for students and educators.

6. Conclusions

The impact of digital reading during educational disruption on science and engineering students' learning experience was investigated in this paper. A survey consisting of Likert questions and open questions was shared with the science and engineering students in Years 2–4 (Levels 1–3) of their study at SWJTU-Leeds Joint School, Southwest Jiaotong

University in Chengdu, China. Based on the results and discussion presented above, the following conclusions can be drawn:

- Compared with the other published studies on general university students in various majors, the current study's findings showed that the behavior of science and engineering students toward digital reading is generally favorable [2]. Additionally, unlike the studies conducted during the pandemic, the current study found that online learning helped some students develop their digital reading skills during the pandemic, not the opposite effect [3]. Most participants in the current study have shown interest in using digital academic reading after educational disruption and their intention to use it in the future.
- Most students use their laptops for digital reading as it is the most common device. It was noticed from the findings that most of the students who are vulnerable to the use of digital academics were junior students. These outcomes are consistent with the previously published studies [3,4,52].
- Although it turns out that a large percentage of engineering students still think that reading in print helps them to remember the information better, it seems that the attitude of science and engineering students is different from that of general university students studying other majors.
- Students prefer digital format for native language reading, while they prefer printed format for foreign language readings. This is because foreign languages might require deep reading, which is more convenient in printed format.
- The outcomes of the study have potential implications for student/educator training, educational policymakers, and the design and use of educational learning technologies. Science and engineering education authorities are advised to provide pedagogical training on digital reading and its integration into student learning.

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