# Reducing the Impact of Emergency Remote Teaching Through an Understanding of Personal Digital Ecosystems

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***Abstract*—This two-phase mixed methodology study, relevant to STEM educational stakeholders and researchers in emergency remote teaching (ERT) and ICT for education, explored college students' and graduates' attitudes and usage patterns of educational ICT in the U.S. and Japan and identified affordances of the technology for both text and audio-based activities of various lengths. The research was divided into two phases, with the first a qualitative analysis utilizing a questionnaire and coding, which informed the second phase, a quantitative analysis of device and activity associations utilizing *k*-means analysis. The findings suggest that these participants have a sophisticated understanding of their personal digital ecosystems and practice a form of dynamic "affordance switching" that matches devices to activities. This is reassuring when considering the need for a sudden move to off-site teaching necessitated by an ERT. The *k*-means analysis identified three main devices out of six commonly used devices and associated those three with specific task characteristics. The Laptop PC was the most universally associated device, followed by the smartphone and traditional paper-based nondigital devices. These findings can inform administrators seeking to supply devices to students during ERT on a limited budget.**

***Index Terms*—Affordance switching, digital ecosystem, education, e-learning, emergency response teaching, Information and Communications Technologies (ICT), metamedia.**

## I. Introduction

THIS research will interest educational stakeholders in the STEM area dealing with emergency remote teaching (ERT) [1] and researchers interested in the affordance of Information and Communications Technologies (ICT) for education, including providing personalized learning opportunities. The COVID-19 crisis forced a shift to either a hybrid learning experience or entirely off-site learning, so requiring a waiving of the usual planning and design [1]. This study developed from this need to understand how ICT could be efficiently leveraged to create an ERT off-site learning environment for undergraduate computer science students at a technical university. This off-site move and the need to minimize the impact on students [2], [3] and faculty [4], [5] motivated this research. If educators can better understand students' ever-evolving personal digital ecosystems [6], [7], this information can inform the development of online learning systems and lessen the impact of ERT while considering the already existing challenges [8]. A better understanding of the digital ecosystems of today's students can inform course design that better fits individual learner expectations instead of forcing them to adopt devices or approaches they rarely use.

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## II. Literature Review

This study addresses gaps in existing research on ERT, which primarily focuses on synchronous tools and text-based resources [9]. It expands the scope to include audio and video modes. While previous literature identifies four crucial ERT themes—learning approaches, delivery modes, design features, and institutional support [10]—this research specifically targets delivery modes. It aims to enhance the understanding of device-to-content relationships, thereby contributing to the broader theme of institutional support in ERT.

Current research underscores the crucial role of technology in mediating education during the pandemic and its impact on the learning process [11]. It stresses the necessity for in-depth comprehension of the interaction between technological tools and educational activities for designing effective online resources [12]. The current study aims to address these issues. This research intersects with studies on ICT integration and user behavior with technology [13] but distinctively concentrates on aligning media in learning tasks with appropriate technologies, which is a less researched area [14].

Metamedia, a concept that captures the evolving nature of modern digital devices, refers to platforms that encapsulate various forms of media, enabling diverse functionalities within a single technological framework. This idea, primarily rooted in Kay and Goldberg's [15] vision of dynamic, multifunctional media systems, underscores how devices like smartphones and computers transcend traditional media boundaries [16], offering an amalgamation of text, audio, visual, and interactive elements.

Concurrently, the notion of "niches" [17], [18] emerges from this technological versatility, denoting the specialized roles or contexts in which these metamedia are utilized [19], [20]. Niches are shaped by the unique affordances of different media within these platforms, illustrating how users adaptively switch between devices and applications to suit specific tasks or content types, ranging from brief text-based interactions to comprehensive multimedia engagements. Collectively, these concepts highlight a nuanced understanding of digital media's role in contemporary communication and information ecosystems.

Building on the concepts of metamedia and niches, switching between affordances emerges as a key behavior in the interaction with digital media. Affordance, a term borrowed from ecological psychology [21], [22], refers to the perceived and actual properties of an object that determine how it could possibly be used. Gibson used the term affordance to represent the relationship between an animal and its environment as a part of his approach to visual perception, which constituted part of his larger ecological approach to psychology [23]. In particular, Gibson's work was influenced by Gestalt psychology concepts, including Koffka's notion of "demand character" [24] and Lewin's concept of "invitation character" or "valence" [21].

According to Norman [22], affordances are connected to the design aspects of an object, which suggests how it should be used, so affordances are bound to an object's usability. It is these affordances that are designated technological affordances. These technological affordances offer a framework from which the aspects affecting usability can be investigated.

However, the affordance of something is invariant, so even though the observer might not perceive or attend to the affordance, it is always there to be recognized. The affordance is not made real by the need of an observer or the act of perceiving it but is an essential part of it [21]. So, an affordance exists, whether it is perceived and used or may even be employed without awareness of doing so. In this sense, technology affordances extend beyond intended uses to include unintended consequences and how users adapt technology in unexpected ways [25]. The rationale of this study is that examining students' perceived affordances of devices they are familiar with will reveal insights into these unforeseen adaptations and uses.

In the context of metamedia, each platform or device offers a unique set of affordances based on its functionalities and the user's perception. Affordance Switching, as defined in this study, involves users actively choosing between different media platforms or devices to capitalize on the specific affordances that best suit their immediate needs or tasks. For instance, a user might switch from reading a brief text on a smartphone, which affords portability and immediacy, to engaging with a lengthy academic article on a laptop, which offers a larger screen and a more conducive interface for extended reading and comprehension. This switching is often influenced by the characteristics of the content, such as its length, complexity, or the mode of engagement it requires. Thus, affordance switching is a dynamic and context-dependent process, reflecting the users' adaptive strategies to navigate the rich media landscape shaped by metamedia and their corresponding niches.

## III. Methodology

### A. Research Questions

The research questions are as follows.

1) What are the students' general attitudes toward educational ICT?
2) What are the student usage patterns of educational ICT?
3) What are the affordances of the technology from the perspective of the students?

This research was designed in two phases, with each having separate data collection and analysis, but both targeting the core research questions. The first phase analyzes qualitative data from open-ended questions on participant technological adoption for educational purposes. This initial phase can be viewed as a type of pilot study intended to inform the design of the second phase of the research. The second phase of the research consists of a quantitative $k$-means analysis of participant responses to questions about specific affordances offered by devices for educational activities.

TABLE I
RESPONDENTS

| Respondents | | |
|---|---|---|
| ***Respondent Age*** | ***Response %*** | ***Response #*** |
| **Phase One (USA)** | | |
| < 18 | 0.00% | 0 |
| 18-29 | 58.65% | 122 |
| 30-44 | 41.35% | 86 |
| Total | | 208 |
| **Phase Two (Japan)** | | |
| 18-24 | 100.00% | 114 |
| Total | | 114 |

### B. Phase One Data Collection and Analysis

The initial data collection was a broad survey (n=208) of college graduates between 18 and 35 years old living in the United States. Similar research has been done in relation to microlesson design [26]. In Table I, the breakdown of the respondents' ages and response rates can be seen. The respondents were 48.08% male and 51.92% female. In this study, a short survey of five open-ended questions was employed to obtain a better understanding of the degree of technological adoption in relation to participants' educational activities. Since this was an exploratory study, five open-ended questions were used to allow a wide range of possible answers from participants [27]. The questions are as follows.

1) What is educational technology?
2) How do you use technology in your education?
3) How does technology improve your education?
4) How does technology hinder your education?
5) Think about the future. What would you like educational technology to do that it does NOT do now?

Question 1 was intended to get a broad definition of what educational technology is for the participants. Question 2 was directed at the uses to which participants put the technology. Questions 3 and 4 give insight into the perceived positive and negative affordances of educational technology. Question 5 is included to shed some light on those affordances the students value but are not available to them. The answers were collected through an online system and classified thematically

TABLE II
CODING RESULTS

| Coding Results | | |
|---|---|---|
| ***Question*** | ***Total References*** | ***Code Theme*** |
| Q1 | 33 | Technology |
| | 19 | Setting |
| Q2 | 22 | Information |
| | 21 | Resources |
| | 15 | Technology |
| | 5 | Setting |
| | 5 | Pedagogy |
| Q3 | 38 | Scaffolding |
| | 13 | Activities |
| | 5 | Resources |
| Q4 | 11 | Learning Curve |
| | 5 | Information |
| | 2 | Technical problems |
| Q5 | 20 | Information |
| | 19 | Technology |
| | 11 | Real-world |

into codes. In line with the exploratory nature of this study, thematic coding was used to allow the coding to emerge from the data as opposed to forcing a predetermined coding. This resulted in 16 coded themes, in Table II, that emerged from these five open-ended questions. These themes represent the factors that the participants perceived as related to their uses of ICT for education.

### C. Phase Two Data Collection and Analysis

The results from the first phase of this research informed the design of the second phase, where the first phase sought to understand the participants' perceptions of their general educational ecosystem and the technology within it, and the second phase sought to capture a detailed understanding of their matching of device affordances to specific activity characteristics. These characteristics included type of communication (speaking, listening, reading, writing), data or material type (text or audio), and six different lengths (1 word, 20 words, 150 words, 500 words, 2000 words, and 50 000 words). Here, speaking refers to recording or spoken communication. These were meant to represent familiar text sizes, which are, respectively, single word, single sentence, single paragraph, single page, short essay, and book lengths.

The second phase of data collection, Table I, consisted of college students in Japan ($n = 114$) consisting of male ($n = 98$) and female ($n = 16$) computer science students between the ages of 18 and 24 years. While the participants of phases one and two are from different cultures, they are similar in the level of technological infrastructure and access. The participants were asked to complete an online survey where they matched six tools or devices used by students with 24 possible activities. The devices were chosen based on the phase one results, which also informed the activity characteristics. In this study, the data was analyzed using $k$-means, but it was previously analyzed using a different technique [28]. In phase one, the participants indicated frequent use of technology for these activities but did not explain if the content characteristics affected their device choice. These tools included both digital and nondigital devices: 1) Desktop PC; 2) Laptop PC; 3) Tablet; 4) E-Reader; 5) Smartphone; and 6) Paper (nondigital).

The inclusion of paper as a device in this study may appear out of place, but justifying this relation between old mediums and new digital ones equips us to more effectively comprehend and analyze these platforms as to their adoption and uses, which allows us to better understand and control the potential future [29].

The participants were asked to indicate which of these devices they would use for each of the 24 tasks. These tasks were divided into four subsections: 1) listening; 2) reading; 3) speaking; and 4) writing. Within each section, there were six different amounts of information. These tasks included the following: 1) Listening [1 word]; 2) Listening [1 sentence (20 words)]; 3) Listening [1 paragraph (150 words)]; 4) Listening [1 page (500 words)]; 5) Listening [1 essay (2000 words)]; 6) Listening [1 book (50 000 words)]; 7) Reading [1 word]; 8) Reading [1 sentence (20 words)]; 9) Reading [1 paragraph (150 words)]; 10) Reading [1 page (500 words)]; 11) Reading [1 essay (2000 words)]; 12) Reading [1 book (50 000 words)]; 13) Speaking (recording/talking) [1 word]; 14) Speaking [1 sentence (20 words)]; 15) Speaking [1 paragraph (150 words)]; 16) Speaking [1 page (500 words)]; 17) Speaking [1 essay (2000 words)]; 18) Speaking [1 book (50 000 words)]; 19) Writing [1 word]; 20) Writing [1 sentence (20 words)]; 21) Writing [1 paragraph (150 words)]; 22) Writing [1 page (500 words)]; 23) Writing [1 essay (2000 words)]; and 24) Writing [1 book (50 000 words)].

The goal was to gain a more granular understanding of the participants' affordance switching, that is, the shifting between devices that offer the best-perceived match of affordance to any given activity. The aggregate responses and $k$-means clustering result can be seen in Table III.

## IV. RESULTS AND DISCUSSION

### A. Phase One Results and Discussion

While this textual coding is a limited data source, it provides insight into students' perceptions of educational technology. These insights could inform the move from on-site to off-site and possibly reduce the ERT impact. The core themes that emerged are listed in Table II and separated by question.

Question one code asks for a description of educational technology, and the themes included "technology" and "setting." Under the broad theme of technology, the term educational technology was described by them as hardware, including computers, tablets, e-books, and smartphones, as well as learning games and any electronic device used for

TABLE III
DEVICE AFFORDANCE SWITCHING

| *K-means Cluster* | *Activity* | *Desktop PC* | *Laptop PC* | *Tablet* | *E-reader* | *Smartphone* | *Paper* |
|---|---|---|---|---|---|---|---|
| 1 | 7 | 34 | 59 | 34 | 17 | 69 | 40 |
| 1 | 8 | 32 | 62 | 34 | 18 | 67 | 37 |
| 1 | 9 | 36 | 74 | 35 | 18 | 50 | 36 |
| 1 | 19 | 33 | 65 | 27 | 8 | 48 | 44 |
| 1 | 20 | 37 | 71 | 27 | 7 | 44 | 42 |
| 2 | 10 | 41 | 87 | 34 | 16 | 24 | 40 |
| 2 | 11 | 38 | 85 | 25 | 12 | 18 | 47 |
| 2 | 12 | 35 | 75 | 22 | 8 | 13 | 47 |
| 2 | 21 | 44 | 85 | 19 | 6 | 23 | 34 |
| 2 | 22 | 45 | 86 | 14 | 4 | 12 | 27 |
| 2 | 23 | 45 | 87 | 8 | 3 | 6 | 27 |
| 2 | 24 | 45 | 83 | 6 | 1 | 5 | 26 |
| 3 | 1 | 29 | 60 | 31 | 12 | 76 | 15 |
| 3 | 2 | 25 | 61 | 31 | 12 | 78 | 14 |
| 3 | 13 | 28 | 51 | 22 | 7 | 67 | 12 |
| 3 | 14 | 29 | 53 | 20 | 6 | 65 | 10 |
| 4 | 3 | 35 | 79 | 29 | 11 | 56 | 9 |
| 4 | 4 | 40 | 84 | 27 | 9 | 41 | 8 |
| 4 | 5 | 42 | 85 | 21 | 9 | 28 | 10 |
| 4 | 6 | 41 | 80 | 19 | 6 | 27 | 13 |
| 4 | 15 | 31 | 69 | 23 | 8 | 48 | 13 |
| 4 | 16 | 31 | 69 | 23 | 6 | 37 | 12 |
| 4 | 17 | 32 | 69 | 17 | 3 | 30 | 12 |
| 4 | 18 | 32 | 66 | 15 | 2 | 28 | 12 |

teaching. This was the main source of the device list used in phase two of this research. The classroom technology included smart whiteboards, projectors, and the Internet. Software apps were also included, such as mobile apps and commercial software like PowerPoint, Zoom, and browsers for YouTube. Regarding ERT, all these technologies would support the move online without the smart whiteboards. This suggests the infrastructure is common in most U.S. schools to support a move to off-site learning. The second theme is setting and includes codes related to the location in which the learning takes place. The codes indicated that educational technology is considered an integral part of in-class and online learning, and a key use was to create a new virtual space in these locations. This again suggests that these respondents were very familiar with online learning, so they may be less impacted by ERT.

In question two, the goal was to better understand how the respondents utilized technology for their education. The first theme is labeled "information" and includes codes related to gathering, distributing, accessing, and collaborating around online data sources. This supports the idea that one of the most valuable uses for technology in education is the interaction with information and the collaboration this makes possible. This is a positive indicator that the respondents could function in a fully virtual learning environment. The pedagogy theme indicated that the respondents had a clear understanding that stakeholders like teachers and students required different information sources, tools, and processes when utilizing technology. Again, this result highlighted the lack of understanding of student affordance switching behavior. Similarly, the setting theme supports the idea that technology is part of learning in the classroom, a blended environment, and completely online. Also, they recognized that most of the education activities could be done online, including full courses, individual lessons, research collaboration, discussions, assignments, and testing. This suggests that a move online due to ERT would not expose them to much that they have not already experienced. This is further supported by the "resources" theme, which indicates that they are familiar with using technology as a means to collect information, especially in video form from sites like YouTube. Finally, the codes that form the technology theme indicate that they identify educational technology as being hardware (computers, smartphones), software (word processors, Duolingo), and online Web services (Google, YouTube).

Question three is similar to question two but asks how technology has improved their educational experiences. The themes coded indicate that technology is integrated into all aspects of education, from learning activities, such as collecting information resources, enabling activities online and in the class, and scaffolding administrative aspects like scheduling and assignment submissions. This again supports the idea that these respondents could handle the administrative issues related to ERT.

Question four looked at the negative effects of technology in education as perceived by the respondents. Information was seen as a problem due to the overwhelming amount available and the difficulty in determining the quality and relevance of the information to the current activity. In addition, the fear of exposing young students to inappropriate or inaccurate information was a concern. This included the problem of distraction when working online, such as having immediate access to near-limitless entertainment. Also, the learning curve associated with new technology, both hardware and software, was mentioned. Finally, the technical issues that frequently affect online learning, such as Internet connection speeds and system crashes, were a concern. While these are legitimate concerns, it would be difficult to ensure that some or all of these issues did not come into play during ERT. These are issues administrators must consider carefully and plan for scheduling adjustments and flexibility in course procedures.

Question five looked at the future of educational technology. The codes here formed three themes: 1) information; 2) technology; and 3) "real-world." The codes that emerged indicated a wish for technology that is more accessible, simple to use, and virtual at a level that can accurately mimic the real-world. In terms of information access, they want technology like artificial intelligence that can rate the quality of information, suggest relevant sources by need, and separate irrelevant information while guiding students through the maze of online sources. The need to automate the reliability rating of information seems to be an important issue. While this is difficult to deal with, it needs to be considered during ERT, when students will have more independent work and, without the usual level of teacher support, may get frustrated and disengage from learning. Recent advances in generative artificial intelligence, such as ChatGPT, may fill this need. The idea of realistic virtual worlds was mentioned several times and, if possible, would be invaluable in an ERT situation. The option of having students enter a virtual classroom, indistinguishable from the real-world, from the safety of their homes, seems to be a popular idea among participants.

### B. Phase Two Results and Discussion

The *k*-means method is a well-known nonhierarchical clustering technique based on the sum of the within-cluster dispersion. The result of the clustering of the students is shown in Table III when we assume the number of clusters to be four. The first column of this table shows the labels of the four clusters that were obtained. The interpretation of this clustering result is shown in Table IV.

The visualization of the *k*-means clustering corresponding to the participant responses is difficult since this data exists in 6-D space (i.e., six kinds of devices), which is not visually representable in our three dimensions. For this reason, Fig. 2 shows the location of the projected data in 2-D space with respect to only Laptop PCs and Smartphones from the 6-D space. In this figure, each color shows obtained clusters in the 6-D space. In Fig. 2 plot, the top cluster is green and corresponds to cluster three in Tables III and IV. Below that is black (cluster 1), then blue (cluster 4), and at the bottom is red (cluster 2).

Fig. 1 shows the centers of the four clusters obtained in the 6-D space and Fig. 2 is the plot of the *k*-means analysis result for the two key devices. It is important to note that since the clusters obtained in the 6-D space are not always the same obtained clusters when using *k*-means for the projected student data in 2-D space, the location of students and the clusters are not coincident with each other in this figure mathematically. However, we can capture the relationship between the obtained clusters with all devices that span the 6-D space and these two devices, which are Laptop PC and Smartphone, from Fig. 2 through the four clusters.

The result of the *k*-means clustering is clear, as seen in Fig. 2. Fig. 2 is the plot of the *k*-means analysis result for the two key devices, Laptop PC and Smartphone, and shows a clear separation of four clusters as indicated by four colors that match the colors in Tables III and IV. The individual activity types are represented in Fig. 2 and Tables III and IV by the numbers 1 through 24, as detailed in Table IV.

All reading and writing activities are limited to clusters one and two, while all listening and speaking activities are only seen in clusters three and four. Cluster one contains only small-sized data with reading from 1 to 150 words and writing from 1 to 20 words. Cluster two includes the higher-word counts, with reading from 500 to 50 000 words and writing from 150 to 50 000 words. Cluster three contains the smaller listening sizes from 1 to 20 words only and speaking the same from 1 to 20 words. Cluster four contains all the larger sizes, with listening from 150 to 50 000 words and speaking the same from 150 to 50 000 words.

These results indicate that the form of the data being manipulated by the participants, text or audio, plays a part in determining the device chosen, with text data being limited to

TABLE IV
*K*-MEANS CLUSTERS

| Activities divided into four clusters | | |
|---|---|---|
| ***Cluster*** | ***Activity #*** | ***Activity*** |
| 1 | 7 | Reading [1 word] |
| 1 | 8 | Reading [1 sentence (20 words)] |
| 1 | 9 | Reading [1 paragraph (150 words)] |
| 1 | 19 | Writing [1 word] |
| 1 | 20 | Writing [1 sentence (20 words)] |
| 2 | 10 | Reading [1 page (500 words)] |
| 2 | 11 | Reading [1 essay (2000 words)] |
| 2 | 12 | Reading [1 book (50,000 words)] |
| 2 | 21 | Writing [1 paragraph (150 words)] |
| 2 | 22 | Writing [1 page (500 words)] |
| 2 | 23 | Writing [1 essay (2000 words)] |
| 2 | 24 | Writing [1 book (50,000 words)] |
| 3 | 1 | Listening [1 word] |
| 3 | 2 | Listening [1 sentence (20 words)] |
| 3 | 13 | Speaking (recording/talking) [1 word] |
| 3 | 14 | Speaking (recording/talking) [1 sentence (20 words)] |
| 4 | 3 | Listening [1 paragraph (150 words)] |
| 4 | 4 | Listening [1 page (500 words)] |
| 4 | 5 | Listening [1 essay (2000 words)] |
| 4 | 6 | Listening [1 book (50,000 words)] |
| 4 | 15 | Speaking (recording/talking) [1 paragraph (150 words)] |
| 4 | 16 | Speaking (recording/talking) [1 page (500 words)] |
| 4 | 17 | Speaking (recording/talking) [1 essay (2000 words)] |
| 4 | 18 | Speaking (recording/talking) [1 book (50,000 words)] |

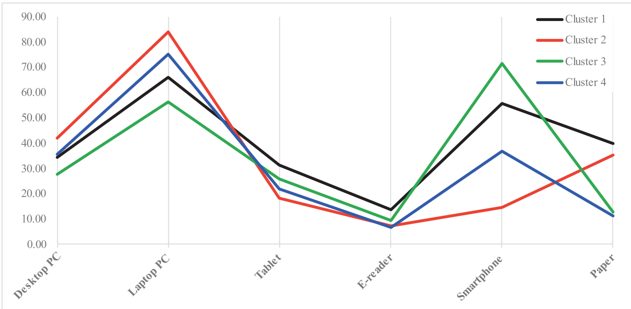


Fig. 1. Summation of device to cluster strength of association.

clusters one and two and audio data limited to clusters three and four. In addition, the size of the data is clearly separated. Text activity data that is relatively small is limited to cluster one, while larger text data is in cluster two. The same can be seen with audio data, with the smaller being in cluster three and the larger in cluster four.

From this result, cluster one can be characterized as reading and writing activities dealing with text material of relatively short size. Cluster two is characterized as reading and writing activities dealing with text material of relatively long size. Cluster three is characterized as listening and speaking activities dealing with audio material of relatively short duration. Cluster four is characterized as listening and speaking activities dealing with audio data of relatively long duration.

Fig. 1 shows the centers of the four clusters obtained in the 6-D space and are prototypes of these four clusters. In Fig. 1, the diversity of the values among four clusters shows the analysis technique could distinguish these clusters, and so the diversity among the four clusters shown is significant in the two variables, which are Laptop PC and Smartphone. The dots in Fig. 2 are the locations of these four clusters in 6-D space projected down to the 2-D space regarding the variables of Laptop PC and Smartphone. But *k*-means is an exploratory data analysis, so the information in Fig. 1 can be interpreted as a representation of the strength of the association between the devices and the four clusters. This exploratory data analysis has successfully discovered this latent structure, and it is represented in Fig. 1.

In Fig. 1, this strength of association can be interpreted as the participants preferring the affordances offered by specific devices for specific task types. The peak above the Laptop PC indicates the affordances offered by this device fit well with all four clusters. This association can also be seen in column four of Table III with the high values of the numbers returned by the *k*-means analysis. While all the cluster association values are high, the highest is for cluster two, which represents reading and writing activities that are relatively long. This indicates that the Laptop PC is the most well-rounded in terms of affordances offered, as perceived by the participants.

The second peak in Fig. 1 is above the Smartphone device, with cluster three being the highest and cluster one being the second highest. This suggests that Smartphones offer the participants affordances suitable for dealing with small amounts of information, either in text form or audio form. But, of these two, short audio forms of information have a slightly stronger

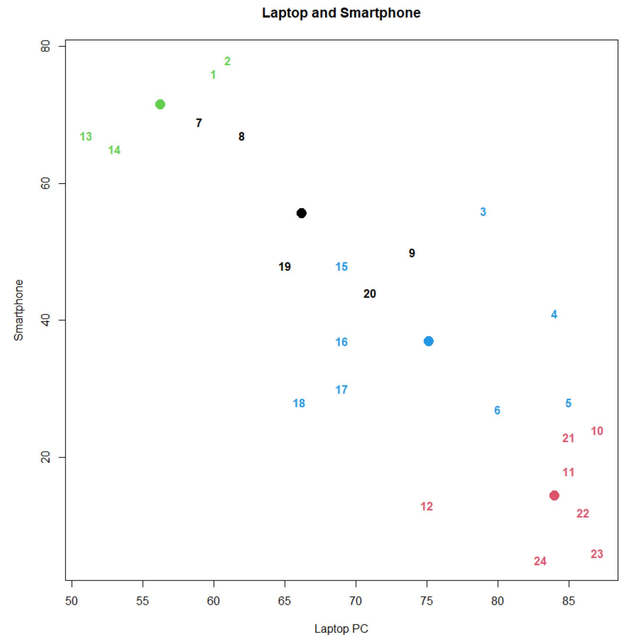


Fig. 2. *k*-means plot of four clusters.

association, such as recording or listening to audio. The least associated cluster with smartphones is cluster two, which is reading and writing long text material. And slightly higher is listening to and speaking longer audio material. Again, these values can be seen in column seven of Table III.

Other devices of interest are paper, here considered a nondigital device, which appears to offer affordances almost equal for cluster one (reading and writing of short text material) and cluster two (reading and writing of longer text material). As expected, paper is perceived as a poor device for dealing with audio. The tablet device has a lower association with all four clusters than paper, but the tablet has higher values for audio material. However, the lowest associations are for the E-reader device, which participants perceive as offering little in the way of affordances for these activities.

These findings indicate that participants recognize that these devices offer differing positive affordances when performing tasks requiring the manipulation of text and audio of differing sizes and lengths. Overall, Laptop PC is preferred for both text and audio materials that are larger and longer, but for shorter materials of the same type, the Smartphone is also perceived as useful. For text-related activities of any size, paper is in third place in terms of perceived association.

## V. Conclusion

The purpose of this research is to better understand how students make use of educational technology. The hypothesis is that a better understanding of the perspective and use students have for educational technology can be applied to the sudden move from on-site to off-site formats precipitated by the ERT to reduce any negative effects on education. This is especially important when considering the digital divide. That is, the availability of funds to secure multiple devices is not always possible, so administrators need to be aware of which single device will offer the most to the students.

This research strongly indicates that college-educated participants have a sophisticated understanding of the nature of their digital ecosystems and the specific advantages offered by devices in that ecosystem. They identified three main devices out of six and associated those three with specific task characteristics. The Laptop PC was the most universally associated device with both text (1 to 50 000 words in size) and audio (1 to 50 000 words in length) data. The strongest of these was the association with longer-form material of both text and audio. However, the Smartphone was perceived as having an equal association with shorter-form data of both text and audio formats. Traditional paper-based nondigital devices were strongly associated with text-formatted materials.

These findings indicate that the negative effects of ERT events can be mitigated by listening to the student-preferred device needs. This means prioritizing the availability of Laptop PC and Smartphone devices and optimizing online lesson materials to fit these devices. However, any students who are not able to access these devices for whatever reason may be at a significant disadvantage, so institutions should survey students and try to provide devices to those in need. The results of this research indicate that institutions with limited financial resources can make this simpler by providing Laptop PC devices whenever possible, as they offer the most well-rounded affordances. Smartphones are also useful, but the students will likely provide these themselves.

As a two-phase study, there are clear limitations to this research. The two separate data collection phases, the second being informed by the first, aided the selection of devices and activities to include in the $k$-means analysis. Both samples draw from similar demographics of college-educated participants in the United States and Japan, which are on par in terms of technological infrastructure and availability. In the future, a larger study is planned with a single data collection sample and expanded to include a broader mixed methodology approach. Here, a $k$-means analysis was performed and indicated clear associations between devices and activity types—referred to here as affordance switching. This can be expanded to use dimensional reduction techniques, such as principal component analysis, to try to get a clearer picture of affordance switching, that is, the learners' act of switching between devices during educational activities in order to best-match device affordances with specific activity types. This will be a focus of future research.

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