Comparative Study of Netbooks and Tablet PCs for Fostering Face-to-Face Collaborative Learning

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Abstract

With the recent appearance of netbooks and low-cost tablet PCs, a study was undertaken to explore their potential in the classroom and determine which of the two device types is more suitable in this setting. A collaborative learning activity based on these devices was implemented in 5 sessions of a graduate engineering course of 20 students, most of whom were aged 22 to 25 and enrolled in undergraduate computer science and information technology engineering programs. Student behavior attributes indicating oral and gesture-based communication were observed and evaluated. Our findings indicate that in the context in which this study was undertaken, tablet PCs strengthen collective discourse capabilities and facilitate a richer and more natural body language. The students preferred tablet PCs to netbooks and also indicated greater self-confidence in expressing their ideas with the tablet’s digital ink and paper technology than with the netbooks’ traditional vertical screen and keyboard arrangement.

1. Introduction

Mobile technologies such as laptops and mobile phones are becoming one of the most commonly used tools in our everyday lives and have overtaken traditional desktop PCs ([1]; [2]), spurring the emergence of widespread access to wireless connectivity. This reality has prompted considerable interest in finding fruitful ways of integrating mobile technologies, such as wireless laptops and tablet computers, into educational settings. Recent studies reveal that participatory learning environments supported by one-to-one mobile computing can foster a richer social interaction context among the students, contrasting sharply with the passive lecture-based methods present in educational institutions everywhere ([3]; [4]; [5]). In the light of these trends, education researchers and practitioners are driven to investigate whether pedagogies supported by mobile technologies can succeed in eliciting better teaching and learning outcomes ([3]; [6]; [7]). Complementarily, human-computer interaction research is concerned with establishing design criteria for technology-supported learning environments, as well as evaluating the usability of mobile technologies in the educational contexts under study ([8]; [9]). In this regard, the variety of mobile devices available nowadays, presenting different characteristics, such as input possibilities and form factors [10], calls for investigating whether device-specific affordances may positively (or negatively) influence teaching and learning processes in the classroom.

According to Fried [11], clearly defined factions have taken sides both for and against the incorporation of wireless laptops into the learning process. A number of researchers examining classroom laptop use have discovered benefits for students such as greater
motivation and willingness to collaborate, better connections between different subject fields, a narrowing of the digital divide, improvements in problem-solving skills and the promotion of academic achievement ([12]; [13]; [14]). Other studies, however, have found evidence that laptops in the classroom can create adverse conditions for learning, limiting or even reducing academic performance ([11]; [15]). Research on this issue is still clearly in its infancy, and as long as the findings remain inconclusive, further investigation of the use of these devices in education is essential ([3]; [16]; [17]).

Although laptops and now netbooks ([18]; [19]) have become very popular and enjoy definite advantages over desktop computers, especially as regards portability, they continue to fall short in applications that demand high mobility or employ drawing and handwriting user interfaces [10]. An ideal alternative that addresses the requirement of mobility and ink-based input capability is the tablet PC, a device that is easy to carry thanks to its slate shape and supports direct interaction with the screen using a stylus, similar to the traditional interaction between paper and pencil.

Ozok et al. [20] note that although a fairly substantial body of research has grown up in the last few years on desktop and laptop usability, very few studies have reported on experiments with tablet PCs. Recent studies focusing on educational applications have reported on the use of tablet PCs for enriching the lecture presentation, i.e., as a digital replacement for the white (or black) board [21], and providing the students digital means for note-taking ([22]; [23]). More recent initiatives have explored supporting collaborative note-taking in the classroom and collaborative learning activities ([24]; [25]). Approaches leveraging tablet PCs in collaborative learning settings have targeted taking advantage of the digital ink affordances provided by the tablet PC as a means to support collaborative resolution of open-ended tasks ([5]; [6]; [26]). Despite the increasing number of experiences involving tablet PCs in the classroom, more research is required in order to establish significant advantages (or disadvantages) of tablet PCs in comparison to laptops in these educational settings.

While laptops and tablet PCs have been widely available in the market for many years, low cost models specifically targeted at education have emerged only recently ([17]; [27]); therefore, less research has been done on these newer technologies. This situation motivates exploring the potential of education-aimed netbooks and tablet PCs with a view to determining which of these devices would be the most appropriate for the classroom.

In this article we offer a comparative analysis of two netbook-type computers designed for educational applications, one presenting a more traditional format (i.e., small size laptop) and the other containing tablet PC features (i.e., slate shape and stylus-based input). They were utilized in this study during lectures for a graduate-level engineering course as a supporting technology for a face-to-face small group collaborative learning activity aimed at solving open-ended questions ([26]; [28]). Each student in the study was equipped with either a netbook or a tablet and the behavior of the groups was observed and compared. Given the particular context in which our study was conducted, the conclusions we obtained cannot be generalized to scenarios involving different demographics or tasks, however, our findings yield evidence supporting specific device features as being more appropriate for supporting collaborative work in the classroom. In what follows we present a description of the collaborative activity (Section 2), the
2. Wireless netbooks geared towards a participative classroom

In the traditional lecture-driven classroom, students must pay careful attention to the instructor and concentrate on carrying out assigned tasks without interrupting others. These strictures discourage rich interaction between the students ([30]; [31]), leaving them little opportunity to develop skills in teamwork, language and interpersonal relations. Wireless netbook technology can help overcome this situation by creating a workspace that fosters participation through collaboration and rich face-to-face interaction.

To examine how wireless netbook devices can be used to promote interaction between students and classroom participation, they must be introduced into the classroom within the framework of a clearly defined pedagogical purpose. In this study, we used a collaborative learning activity known as CollPad ([26]), which relies on 1:1 mobile computing (e.g. PDAs, netbooks, tablet PCs) to support students in solving open-ended questions assigned by the instructor, related to the material covered in class.

The educational value of CollPad has been assessed and reported by previous studies conducted in engineering courses at the Pontificia Universidad Catolica de Chile [28] and in K-12 classrooms in Chile and the UK [26]. The studies assert that CollPad offers a constructivist model of knowledge building, which fosters an environment favorable for the development of communication, interpersonal and decision-making skills, and ensures interaction between class members who do not normally work together, by means of composing the work groups randomly.

In the initial Individual Response phase of CollPad, the students all receive the assigned question from the instructor on their devices, and each of them writes his/her individual answer without interacting with their group mates. The software installed on the devices supports editing on virtual paper by means of a text tool, which writes text with user-configurable font attributes (size, color, etc.) and a pen tool that draws using a pointing device (touchpad, stylus or mouse) in a range of line weights and colors. Handwriting created with the pen tool is preserved as such, with no automatic recognition or conversion into text.

In the second CollPad phase, denoted Collective Decision, students see their group mates’ answers on their device screens, and must then discuss which one of them to send to the instructor. Alternatively they may decide on a new response (the New Proposal phase), in which case one group member is elected to the role of the scribe while the other members, acting as reviewers, agree on the response text before the scribe writes and submits it.

As the students generate and send in their group answers, the instructor reviews them on his/her device and selects those he/she considers most suitable for initiating a discussion involving the whole class. Members of the groups whose responses were chosen may be called before the class to argue for and justify them.
3. Classroom experiment

This study sought to determine how netbooks and tablet PCs impact technology-supported collaborative work activities in the classroom. In a previous study [28], we observed the use of the CollPad method in a classroom using handheld devices (PDAs) to validate the ability of this technology tool to stimulate the development of students’ language, interpersonal and decision-making skills. Given the rising popularity of netbooks, we believe they can be a practical alternative for conducting collaborative classroom activities. Thus, in the experiment reported here we again observed a CollPad activity, but this time to compare conventional and tablet-style netbooks in order to establish which device type better empowers classroom communication and interaction.

3.1. Context of observed activity

The context for the activity experiment was the Knowledge Management course taught in the first semester of 2009 at the School of Engineering of the Pontificia Universidad Catolica de Chile. The course consists of weekly lectures and its objective is to increase students’ awareness of the significance of human beings amid the dizzying pace of current technological development in order to better comprehend their role in this process and how to take part in it.

Before the observations pertaining the present study were undertaken in the Knowledge Management course, the students were briefed about the nature of the study and introduced to the two kinds of devices involved. All the students in the course accepted being involved in the experience. Activity sessions were carried out in 12 classes during the semester, always following the same dynamic. The activity itself was held in the last 30 minutes of the class period. Mobile devices were handed out randomly to the students, CollPad was launched and the group (randomly formed) each was assigned to was indicated on his/her device screen. Once they were all sitting face to face in their respective groups, the instructor sent an open-ended question related to the material covered in the first part of the class and the activity proceeded as described in Section 2.

3.2. Tasks in the observed activity

The tasks the students solved using CollPad in the Knowledge Management course consisted solely of open-ended questions. These were designed by the instructor to strengthen the students’ abilities in understanding and critically analyzing the ways in which people’s day-to-day lives are built, modeled and influenced by cultural contexts. In most cases, more than one answer to the question was acceptable; the instructor was in control of steering the discussion towards the answers he considered was the best one. None of the questions demanded that the students elaborated their answers in a schematic or pictorial way, but rather, all of the questions could be responded with concise explanations in sentences.

Each CollPad task was related with the subject matter being taught in the lectures, and required that students choose and apply suitable concepts in their answers with proper justification. For example, the course had a unit dedicated to a general model about people’s understanding of the world. The CollPad task for that specific unit consisted in
first having the students watch a video of an orchestra interpreting John Cage’s ‘4’33’’
composition. ‘4’33’’ is a special composition because the score instructs the whole
orchestra not to play the instruments during the entire duration of the piece.
Consequently, the resulting interpretation of the piece consists of the sounds of the
environment that the listeners hear while it is performed. At the end of the interpretation
shown to the students on video, the audience applauds vigorously. The task for the
students in CollPad was to explain why the audience applauded after ‘4’33’’ of silence,
according to the model seen on class.

The format of the other CollPad tasks in the experience was similar in the sense that the
students had to elaborate how a real-life issue could be understood with the models taught
in class. The students could elaborate valid answers using any type of input on their
devices, such as keyboard or digital ink (i.e. stylus input). Drawings, schemas or special
symbols were not required, thus the tasks were not biased towards benefiting students
with devices supporting digital ink capability (i.e. tablet PCs or PDAs).

3.3. Hardware used during the study

For the first 7 of the 12 sessions, the activity was performed using a version of CollPad
on HP iPAQ rx1950 Pocket PC (PDA) devices, as described in Alvarez et al. [28]. In the
last 5 CollPad sessions, the students worked with two types of Intel Classmate netbook
devices designed for the classroom: the first generation Classmate PC [27] (hereafter
CMPC) and the Convertible Classmate PC (hereafter C-CMPC). In order that the two
technologies could be compared, CollPad ensured that all students assigned to a given
group had the same device type, whether CMPC or C-CMPC.

The CMPC we used was a 7-inch screen netbook powered by a 900 Mhz Celeron
processor, with 2 gigabytes of flash memory, 512 megabytes of RAM and WiFi
capability. The C-CMPC, on the other hand, had an 8.9-inch touchscreen that supports
user interaction through a stylus and can be rotated and folded down over the keyboard. It
featured a 1.4 Ghz Intel Atom processor, 1 gigabyte of RAM, a 40 gigabyte hard disk
drive and WiFi capability. Both devices ran the Microsoft Windows XP operating
system.

3.4. Observation procedure

To observe and analyze the work performed by the students during the activity sessions,
data were collected from three different sources. First, four groups of students were
filmed, two of which were working on CMPC devices and the other two with the C-
CMPCs. Individual cameras were employed for each group. To obtain a more accurate
recording of the group conversations, the sound was also captured separately using MP3
digital audio players. The instructor-mediated discussion in the final phase of the activity
was always filmed with a single camera.

The second data source was a survey of the students conducted at the end of the semester
to gather information on their experiences, criticisms and views of each of the technology
types. Finally, the third source was the data stored in the instructor’s device on the groups
who were chosen by the instructor for the final (whole-class) discussions to determine the
relationship between the frequency with which groups were so chosen and the device they used.

3.5. Description of the samples

The experimental observations for the comparative analysis between CMPC and C-CMPC devices were conducted on the last 5 sessions of the Knowledge Management course, involving 20 students, most of whom were aged 22 to 25 and enrolled in undergraduate computer science and information technology engineering programs. All of the students were already familiar with the PDA version of CollPad, and all of them were skilled at operating Windows based laptops. However, few students did not have prior experience operating tablet PCs, therefore, basic instructions on how to use the stylus of the C-CMPC and how to convert the device to slate format were given to them before starting the experimental observations. The version of CollPad for CMPCs and C-CMPCs has a similar user interface to the PDA version the students had used previously, thus no additional training was required for the students to become familiar with the new CollPad software.

3.6. Device and group assignment

![Diagram showing device assignment to students.]

Fig. 1: Devices assigned to each student while being under observation throughout the sessions.

In each of the 5 CollPad sessions observed, the group composition policy was random student-to-group assignment; hence the group composition was different and unpredictable in each session [29]. For the comparative analysis, in each of the 5 sessions 4 groups were observed (i.e. filmed): two of them using C-CMPCs and the other two CMPCs. Therefore, throughout the 5 sessions 20 groups were observed in total (10 equipped with CMPCs and 10 with C-CMPCs). Noticeably, each individual student was observed a random number of times throughout the sessions due to the random group composition criteria used (see Fig.1).

At the beginning of each CollPad session, a CMPC or C-CMPC device was assigned to each student fortuitously. When the CollPad software was initialized on the devices, each student was randomly assigned to a group of three students. There were always two groups (and therefore 6 students) in the activity that used C-CMPCs, while all the other groups used CMPCs. This was so because only six C-CMPCs were available for student use, with one additional unit reserved for the instructor. The groups using C-CMPCs were always observed during the CollPad sessions, while other two groups using CMPCs
were randomly chosen for observation. Considering that the student attendance varied in each session, the total number of groups differed among sessions as shown in Table 1. Given that only 4 groups were observed in each session, there were groups using CMPC devices that were not sampled for empirical data.

Fig. 1 shows the devices that were assigned to each student while being under observation throughout the five sessions. With the resulting random assignment of devices and groups on each session, it can be seen that while most students used a C-CMPC at least twice, only three students (2, 14 and 15) did not have a chance to use a C-CMPC at all. On the other hand, two students were not observed using a CMPC (12 and 19). However, by inspection of the video footage recorded, the latter students could be found using CMPC in groups that were not observed, thus it is possible to affirm that all the students in the cohort had the chance to work with a CMPC.

4. Results

The students’ work as captured on the audiovisual recordings was reviewed and evaluated on an observation form based on Infante et al.’s [32], adapted to the aims of our study. The review and evaluation process sought to ascertain whether groups using CMPC and C-CMPC devices presented any significant differences in the quality of their communications depending on the devices used. The evaluation was based on oral and gesture-based communication categories. The oral communications category was concerned with the observation of bidirectional and multidirectional dialogues within a group, and the gesture-based communication category covered characteristics of gestures accompanying oral expression. Gesture-based communications were included in our observation criteria given that they are indicative of a more expressive and natural face-to-face communication between persons [33], [34]. We were therefore interested in determining whether there are differences in this aspect between CMPC and C-CMPC.

The observation process focusing on communications was motivated by previous evidence of CollPad’s potential of generating a rich interaction environment in the classroom [28]. This benefit of CollPad has been found possible thanks to the portability and mobility of the handheld devices used (i.e., PDAs), which facilitate effective face-to-face communications in collaborative work. By contrast, standard desktop PCs and larger laptops can hinder the quality of face-to-face communications in collaborative work [10]. Since both CMPC and C-CMPC devices are larger than PDAs we paid special attention to the way they affected communications and how they differed in this aspect.

4.1. Observation form

The observation form used in the audiovisual evaluations for assessing the group collaborative work was based on the above-mentioned communication categories, each of which was defined by a series of attributes whose corresponding measure is quantitative, reporting the total number of occurrences observed. The attributes of the oral communication category (see Table 2) included person-to-person dialogues, observed when a person talked to one of his/her companions, and person-to-group dialogues, taken into account when a person talked to his/her group mates. The attributes of the gesture-based communication category included hand gesticulation in person-to-person and
person-to-group dialogues, in events in which a group member talked to one of his/her companions pointing to his/her device’s screen with hands/fingers, a person held the device with his/her hands or moved it (e.g. rotated) it to communicate, and where a person moved his/her device aside on the desk due to discomfort when communicating.

In the observation process for the attributes in the observation form, the observers watched the video material simultaneously and recorded the number of events (i.e. occurrences) identified for each attribute in separate logs. The logs had a two-column layout: a column for the timing of the events, and a column for their classification, indicating category and attribute. Whenever an event was encountered, one of the two observers paused the video playback (being the playback controls available to both of them) and both of them registered the timing of the event in their respective logs. The identification of the attribute to which each event corresponded was often a matter of discussion between the observers. For instance, in particular scenarios for the observers it was not easily recognizable whether an event of verbal communication was in person-to-person or person-to-group modalities. In such cases, the observers had to analyze the respective conversation repeatedly until they could make a consensual decision on the attribute to which the event corresponded. When the observers finished analyzing a group, they checked their event logs forms for consistency. If discrepancies were still found, they analyzed the conflicting events and discussed them until they reached a consensus.

To make an objective comparison between CMPC and C-CMPC devices, we conducted mean-comparisson $t$ tests on the previous data, for the two independent samples assuming different variances in them, using STATA 10 software. The tests were based on a null hypothesis $H_0$: $\text{mean}(\mu_{\text{C-CMPC}} - \mu_{\text{CMPC}}) = 0$ (i.e. the difference between the mean frequencies observed for C-CMPC and CMPC is zero), and alternative hypotheses $H_a^1$: $\text{mean}(\mu_{\text{C-CMPC}} - \mu_{\text{CMPC}}) < 0$ (henceforth left-tailed test), $H_a^2$: $\text{mean}(\mu_{\text{C-CMPC}} - \mu_{\text{CMPC}})$ not equal to 0 (henceforth two-tailed test), and $H_a^3$: $\text{mean}(\mu_{\text{C-CMPC}} - \mu_{\text{CMPC}}) > 0$ (henceforth right-tailed test). Significance was based on a 95% confidence level ($p = 0.05$). The last three columns of Table 2 show the $p$-values obtained on the left-tailed, right-tailed and two-tailed $t$ tests, respectively.

The results show that the differences in mean frequencies are significant in favor of the C-CMPC on the person-to-group attribute both in oral and gesture-based communication. The observers’ qualitative appreciation of these differences is that C-CMPCs used in slate format may promote dialogues in the groups with notoriously increased body language (i.e. hand gestures), compared to CMPCs with traditional vertical screen and keyboard arrangement. When using CMPC devices, the students tended to keep their eyes constantly on the vertical screen, which at the same time acted as a barrier to attaining the more fluid face-to-face communication that was perceived in groups using C-CMPCs. With both CMPC and C-CMPC devices, there is a positive correlation between oral and gesture-based communication in person-to-group utterances. The Pearson’s correlation coefficients obtained for these variables were 0.85 in the case of C-CMPC, and 0.66 for CMPC. The correlation between oral and gesture-based communications in person-to-group utterances is stronger with the C-CMPC devices, which is consistent with the group behavior that was perceived by the observers (i.e. group members had a propensity
to gesticulate more when speaking). This behavior is consistent with previous research from [35], which argues that devices with vertical screen arrangement (e.g. desktop PCs or laptops) are prone to hinder proper communication and coordination in face-to-face collaborative activities. C-CMPC devices in slate shape format may therefore facilitate a more fluid and natural face-to-face communication [33], [34] in the context defined by this study.

4.2. Survey

At the end of the semester, the students who participated in the experiment were surveyed to obtain their views of CollPad and their feelings and opinions regarding the devices they worked with. In the following sections we report on the method for the survey and give a detailed account on the results.

4.2.1. Method

The survey was delivered to the students as a paper-based questionnaire and conducted with all the students in the cohort present. It contained 27 questions that were asked as Likert items on a five-level scale (i.e. level 1 associated with “strongly disagree” and level 5 associated with “strongly agree”), 6 open-ended questions on the best and worst aspects of using the CollPad software on C-CMPC, CMPC and PDA devices, plus one final question asking which device they preferred. The Likert-item questions were divided into two groups according to their aims: (1) questions for comparing and contrasting students’ opinions about specific CMPC and C-CMPC features and affordances, and (2) questions for querying students’ opinion about specific device features when used in the CollPad activity. To make an objective quantitative data analysis we performed $t$ tests on the sample data, computed using STATA 10 software. For the first group of Likert-item questions, paired-samples $t$ tests were conducted, with null hypothesis stating equal means in answers to questions comparing C-CMPC and CMPC features (i.e. $H_0$: mean($\mu_{C-CMPC}$-$\mu_{CMPC}$) = 0, rejected with $p$-value < 0.05), and alternative hypotheses $H^1_1$: mean($\mu_{C-CMPC}$-$\mu_{CMPC}$) < 0, $H^2_1$: mean($\mu_{C-CMPC}$-$\mu_{CMPC}$) not equal to 0, and $H^3_1$: mean($\mu_{C-CMPC}$-$\mu_{CMPC}$) > 0. For the second group of Likert-item questions, univariate-sample $t$ tests were conducted with null hypotheses stating a sample mean equal to the neutral value of the Likert scale (i.e $H_0$: $\mu = 3$, with 3 being the neutral value in the scale from 1 to 5), and alternative hypothesis analogous to the ones listed above. These tests sought to determine whether the sample mean differed positively or negatively from the neutral value of the Likert scale at the 95% confidence level.
4.2.2. Results

The students could generate answers for the tasks in CollPad by using any of the available inputs in the devices, i.e., keyboard, touchpad or stylus. Given that both CMPC and C-CMPC devices present reduced size keyboards due to the devices’ constrained dimensions, the students were queried about their acceptance of the keyboards in both devices as an input method for generating answers in CollPad. The results shown on Fig. a favor the C-CMPC over the CMPC, however, these results are not statistically significant ($t(19) = 1.75, p > 0.05$). Notably, the $t$ test with the alternative hypothesis $H_a$: $\text{mean}(\mu_{\text{C-CMPC}} - \mu_{\text{CMPC}}) > 0$ reported a significant $p$-value $= 0.0481$, which can be interpreted as the keyboard of the C-CMPC not being less comfortable than the keyboard of the CMPC. This is consistent with the fact that the students preferred the C-CMPC’s keyboard to the CMPC’s with predominately neutral or less unfavorable opinions. In this regard, the observers of the audiovisual material reported that those who used C-CMPCs rarely entered text on the keyboard, preferring to write by hand on the screen with the device’s stylus.

Regarding screen size, no statistically significant difference was found in the students’ preference for screens on CMPC or C-CMPC devices ($t(19) = 0.698, p > 0.05$). However, most of the students in the cohort found that both devices’ screens were adequately sized for the use of CollPad (Fig.2b). The fact that the diagonal measurement of the C-CMPC screen is 2 inches larger than that of the CMPC was not considered relevant by the cohort.
Fig. 3: In CollPad, answering questions often involved making drawings, which was facilitated by C-CMPC due to its stylus handwriting input which is relatively easy to read.

Fig. 4: The majority of students agreed that with the C-CMPC, ideas could be expressed better than with the CMPC.

In regard to the students’ perception of the added value of using a stylus in CollPad, as indicated on Fig. 3a, the majority of respondents considered that the C-CMPC stylus was a good complement to the keyboard for writing answers in the activity ($t(19) = 5.51, p < 0.05$). Furthermore, this view was naturally related to the general opinion that it was both desirable and useful to be able to include drawings with answers ($t(19) = 6.33, p < 0.05$) (Fig. 3b), which cannot be done efficiently with the CMPC touchpad due to its awkwardness and lack of precision for drawing tasks (Fig. c). In this regard, the students showed no significant difference in their preferences for touchpad input on CMPC and C-CMPC devices ($t(19) = 0.568, p > 0.05$). Concerning handwriting using the stylus (Fig. 3d), the majority of students had an either positive or neutral opinion about the readability of the handwritten text. The corresponding test, $t(19) = 1.37, p > 0.05$, indicates that the students may be indifferent to the readability of the handwritten text, as the null hypothesis is not rejected and the hypothesized neutral value of the Likert scale, i.e. 3, falls into the respective 95% confidence interval (2.84, 3.75).
Fig. 5: The C-CMPC facilitated person-group communication and most students felt more motivated working with this device.

The number of students supporting that the C-CMPC allows expressing ideas better than the CMPC (Fig. 4) was as much as four times the number of students that disagreed with this view, and this result was found to be statistically significant ($t(19) = 2.85, p < 0.05$). Arguably, the fact that the C-CMPC allows handwriting and drawing meant that students could express their ideas better using the C-CMPC. As explained on Section 3.2, none of the tasks observed compelled the students to make drawings, hence, a significant number of students intuitively preferred using the stylus to express their ideas through combining handwriting and drawings.

Twelve students stated that the C-CMPC facilitated communication with their group mates (Fig. 5a), compared to only one student that agreed so about the CMPC. Notably, the difference in the students’ opinions, favoring the C-CMPC, is statistically significant ($t(19) = 2.34, p < 0.05$) and consistent with the results of the observations conducted on the audiovisual material presented on Table 2. With regard to motivation using the devices, the number of students that reported greater motivation to work in CollPad by using a C-CMPC almost doubled the number of students that felt motivated by using a CMPC (Fig. b). However, this difference was not found to be statistically significant by a very narrow margin ($t(19) = 2.07, p = 0.0528 > 0.05$).

Regarding the question for device preference, 11 students favored the C-CMPC, 7 the PDA and only 1 the CMPC, with two not responding. They also showed a clear inclination towards devices with touchscreens and stylus input. Preference for PDAs over CMPCs together with the evidence on Fig. 2b commented earlier, support the fact that students do not necessarily value a larger screen size for writing open answers in CollPad. According to group conversations found in the recorded video material, few students declared feeling forced to write more concise answers when constrained to a smaller screen size, and had a positive appreciation of this limitation. The course instructor shares this view, however, further empirical data is required to support this fact.
Fig. 6: Students agreed that CollPad made a valuable contribution to the process of understanding and learning the course material.

In response to a question about CollPad, the students indicated that they considered it a valuable contribution to the Knowledge Management course (Fig. ). This result suggests that the CollPad activity was a success, and it is consistent with results obtained from experiences in the same course in the previous year [28]. CollPad fulfilled its aim of generating discussion of course material covered in class and fostering the active participation of students through collaborative work.

4.3. Time elapsed in CollPad phases

The elapsed times in the Individual Response and Collective Decision phases of CollPad were recorded for each group in the video analysis conducted by the observers. Comparative statistics for the elapsed times in the Individual Response and Collective Independent sample t tests were conducted on the means of the recorded times of groups working with each kind of device, in an analogous manner to the t-tests conducted on the observation form data.

The results show that groups using C-CMPC devices took in average 25% less time in completing the Individual Response phase of CollPad than students using CMPCs. This result is statistically significant ($t(16) = -2.54, p < 0.05$), and consistent with the students’ perception of the CMPC’s input devices reported on the survey, which regarded the input devices as uncomfortable for typing (keyboard) and inadequate for making drawings (touchpad). Contrastingly, the students reported on the survey that the C-CMPC’s stylus is a good complement of the keyboard and the touchpad. Hence, the students’ positive perception of the stylus may be also related to the fact that they can write their answers more efficiently and more comfortably using this input device.

The results obtained for the elapsed times in the Collective Decision phase of CollPad are opposite to the results of the Individual Response phase, as groups using C-CMPC devices took in average 47% more time in the Collective Decision phase than groups using CMPC devices. This result was also found to be statistically significant ($t(17) = 2.46, p < 0.05$). Arguably, this result can be related to the fact that groups using C-CMPC devices presented significantly more dialogues (i.e. person-to-group utterances) than groups using CMPC devices (see Table 2), thus it is probable that the C-CMPC devices influenced the students’ attitude towards being more open to thoroughly discuss their views and negotiate consensus before submitting the final answer to the instructor,
however, an extensive analysis of the dialogues would be necessary to support this finding.

4.4. Answers selected for CollPad discussions

As explained previously, in each CollPad session the instructor assigned the students an open-ended question on the material covered earlier in the class. The instructor evaluated the different group answers received to determine which had the most potential for stimulating a lively debate as part of a whole-class collaborative task in which a range of complementary, opposing and conflicting visions would be expressed. The CollPad system allowed for a maximum of 4 such group responses to be chosen. These may or may not have included responses from the 4 groups in the sample, as the total number of groups in the CollPad sessions was always at least 5.

Table 4 indicates the number of groups selected by the instructor for the discussion with each kind of device. Notably, in almost all the discussions, except for session 2, the answers generated by the two groups using C-CMPCs were selected for the discussions. However, there is no evidence supporting that answers generated using C-CMPCs were consistently better in relation to the pedagogical objectives than answers generated using CMPCs. As a matter of fact, not all the answers selected by the instructor for the discussion were necessarily correct. In most sessions, this was done intentionally by the instructor for fostering discussions with opposing and/or conflicting views. Moreover, it is possible that the instructor may have been subjectively biased towards privileging selection of answers generated by C-CMPCs. Given that the instructor was not tested for such a bias, by means of the results obtained it is not possible to establish an objective relationship between the instructor’s selection of answers for the discussion and the quality (i.e. correctness) of the answers. In total, the instructor selected 9 answers from each kind of device for the CollPad discussions, and there were always more groups using CMPC than C-CMPC devices, thus there was an evident tendency of the instructor to select answers generated by groups using C-CMPC devices.

5. Discussion

The observations conducted on the audiovisual material together with the results of the survey lead us to conclude that the tablet type of netbook used in the slate format promotes fluid physical and verbal interaction between students, stimulating person-to-group dialogue and integrating all group members in group discussions. Using these devices the students were less inhibited about expressing their points of view and in complementary fashion were more willing to listen to others. On the other hand, it was recurrently observed in the audiovisual material that when the students used netbooks with traditional vertical screen and keyboard arrangement they tended to be immobilized by the need to keep their eyes constantly on the screen. This resulted in the group members limiting their body language when expressing themselves, and confining their conversation to the group mate sitting next to them, rather than communicating with the group as a whole. The experiment was thus conclusive in measuring a statistically significant quantitative difference both in oral and gesture-based communication,
therefore indicating that tablet-style devices can facilitate a richer face-to-face communication in small group collaboration scenarios.

The results also show that in the context of a technology-supported small group collaborative learning activity such as CollPad, in which open-ended questions may be answered using both text and drawings, the students expressed a clear preference for tablet PC and PDA devices with their stylus-based input that facilitates drawing and handwriting, even though none of the tasks assigned to the students required them to make drawings. Although netbooks with touchpads also support drawing, the students’ experience revealed that for the purposes of answering the questions put to them this capability was dysfunctional. In this regard, according to the instructor’s own testimony, he preferred the responses generated by the students working on the C-CMPCs due to their greater expressive capacity.

6. Conclusions and Future Work

Our findings indicate that in the context in which this study was conducted, students prefer tablet PCs to netbooks. Tablet PCs strengthen collective discourse capabilities and facilitate a richer and more natural body language. The students also indicated greater self-confidence in expressing their ideas with the tablet’s digital ink and paper technology than with the netbooks’ traditional vertical screen and keyboard arrangement. Thus, at the same time as the CollPad pedagogical model used in this study facilitates face-to-face collaborative work [28], the use of tablet PCs improve the communication of ideas within the work groups.

Given the specific context in which the present study was conducted, involving a cohort of limited size comprising students in technology-related fields with high skills in operating both the hardware and software involved, our future efforts will aim at pursuing the generalization of the current findings, based on further experimentation with larger cohorts and different courses, not necessarily restricted to the engineering curricula. We also embrace the possibility of conducting more thorough studies for establishing relationships between the devices used to support collaboration and academic achievement.

7. Bibliography


8. **Appendix: Survey**

1. The CollPad software is confusing.
   - [ ] Strongly Disagree
   - [ ] Disagree
   - [ ] Neutral
   - [ ] Agree
   - [ ] Strongly Agree

2. I like using the CollPad software.
   - [ ] Strongly Disagree
   - [ ] Disagree
   - [ ] Neutral
   - [ ] Agree
   - [ ] Strongly Agree

3. The CollPad software is frustrating.
   - [ ] Strongly Disagree
   - [ ] Disagree
   - [ ] Neutral
   - [ ] Agree
   - [ ] Strongly Agree

4. I would like to participate in CollPad activities in another course.
   - [ ] Strongly Disagree
   - [ ] Disagree
   - [ ] Neutral
   - [ ] Agree
   - [ ] Strongly Agree

5. CollPad was a valuable tool in the course.
   - [ ] Strongly Disagree
   - [ ] Disagree
   - [ ] Neutral
   - [ ] Agree
   - [ ] Strongly Agree

6. The tablet PC keyboard is comfortable.
   - [ ] Strongly Disagree
   - [ ] Disagree
   - [ ] Neutral
   - [ ] Agree
   - [ ] Strongly Agree

7. The netbook keyboard is comfortable.
   - [ ] Strongly Disagree
   - [ ] Disagree
   - [ ] Neutral
   - [ ] Agree
   - [ ] Strongly Agree

8. The netbook’s screen size is adequate for CollPad.
   - [ ] Strongly Disagree
   - [ ] Disagree
   - [ ] Neutral
   - [ ] Agree
   - [ ] Strongly Agree

9. The tablet PC’s screen size is adequate for CollPad.
   - [ ] Strongly Disagree
   - [ ] Disagree
   - [ ] Neutral
   - [ ] Agree
   - [ ] Strongly Agree

10. When working with CollPad, my handwritten annotations on the tablet PCs are easy to read for my classmates.
    - [ ] Strongly Disagree
    - [ ] Disagree
    - [ ] Neutral
    - [ ] Agree
    - [ ] Strongly Agree

11. It is desirable and useful to make drawings in CollPad answers.
    - [ ] Strongly Disagree
    - [ ] Disagree
    - [ ] Neutral
    - [ ] Agree
    - [ ] Strongly Agree

12. The netbook’s trackpad is useful for making drawings in CollPad answers.
    - [ ] Strongly Disagree
    - [ ] Disagree
    - [ ] Neutral
    - [ ] Agree
    - [ ] Strongly Agree

13. The tablet PC’s trackpad is useful for making drawings in CollPad answers.
    - [ ] Strongly Disagree
    - [ ] Disagree
    - [ ] Neutral
    - [ ] Agree
    - [ ] Strongly Agree

14. For writing answers in CollPad, the tablet PC’s stylus is a good complement for the keyboard and the trackpad.
    - [ ] Strongly Disagree
    - [ ] Disagree
    - [ ] Neutral
    - [ ] Agree
    - [ ] Strongly Agree

15. In CollPad I express my ideas better when working with a tablet PC than a netbook.
    - [ ] Strongly Disagree
    - [ ] Disagree
    - [ ] Neutral
    - [ ] Agree
    - [ ] Strongly Agree

16. In CollPad activities the tablet PC facilitates my conversations with my group mates.
    - [ ] Strongly Disagree
    - [ ] Disagree
    - [ ] Neutral
    - [ ] Agree
    - [ ] Strongly Agree
17. In CollPad activities the netbook facilitates my conversations with my group mates.
   ○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

18. I feel motivated working with a tablet PC in CollPad.
   ○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

19. I feel motivated working with a netbook in CollPad.
   ○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

20. I like netbooks better than tablet PCs.
   ○ Strongly Disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly Agree

21. Which kind of device is better for working with CollPad, PDA, tablet PC or netbook?

22. Describe the best of the tablet PC in one line.

23. Describe the worst of the tablet PC in one line.

24. Describe the best of the netbook in one line.

25. Describe the worst of the netbook in one line.

26. Describe the best of the pocket PC in one line.

27. Describe the worst of the pocket PC in one line.