The Physicality of Technological Devices in Education:

Building a digital experience for learning

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***Abstract*—Technological devices are being rapidly adopted into schools for education, but we have limited understanding of the value and ways through which the devices can benefit learning. As opposed to research placing the value of these devices in terms of digitality, we make use of theories of embodiment to understand how the physicality of the devices can support learning and sensemaking. We conducted a month-long study to collect data on students' strategies, patterns, attitudes and behaviors toward the use of a suite of devices, for the completion of a course assignment. Themes uncovered include the objectification of information, the immediate awareness of possibilities, an expectation of interaction, coherence of interaction and territorialization of technology spaces. We present a model for the role of physicality of devices with regards to educational activities, and argue for the need to construct a digital ecology to provide a cohesive experience of learning.**

Keywords: Physicality ; learning ; sense-making ; digital devices ; embodiment ; experience ; ecology

I. Introduction

Since the launch of the *Apple iPad* in 2010, many have touted the new device as having great potential for education. From the elementary to tertiary level, schools have been quick to launch pilot programs that hand out *iPads* to students and teachers [1-3]. However, such devices are often introduced into schools without full understanding of their effect on learning. Despite their pervasiveness, we have limited understanding of how to effectively use them in education. The educational benefits of tablets, laptops, PDAs and others are often summed up in the value of the applications installed (e.g. [4]). There seems to be an implicit assumption that mere connectivity and access to content through the devices is a sufficient condition for learning [5]. Much research has thus been carried out on e.g. use of e-learning environments, Web 2.0 or wireless connection on mobile devices.

A key problem from looking at the benefits of technological devices as being mostly in the digital realm is that digital media is immaterial, invisible, and ephemeral. At first glance, this seems counter to theories that emphasize the importance of physicality and embodiment for learning. In this paper, we ask the question of whether the new class of technological devices used in education brings about a lack of a 'physical' or 'persistent' handle. How does the physicality of devices, or their mere existence in the educational context, impacts learning, thinking and sensemaking processes?

II. The Physicality of Digital Media

Digital media is not only about digitality. Our embodied nature means that even digital media has to be necessarily framed in a physical form factor to allow for interaction. As succinctly expressed by Buscher [6], physicality is not just about the physical properties of matter, more importantly, it is about "the effect of interaction". Many have advanced the significance of physicality to influence thinking. According to Vygotsky's [7] mediation theory, artifacts, acting as externally-instantiated signs ('material carriers'), have a mediating effect on higher-level processes (thought). Others like Polanyi [8], Heidegger [9] and Papert [10] also proposed theories pointing to the underlying message that the study of the physical manifestation of digital media in the form of artifacts and tools, as actualized in an educational context is a worthy effort. We did a study to investigate the affordances of the new devices, the conditions they provide for knowledge construction to occur, and ways in which they are integrated into students' workflow.

III. Study Description

The month-long study was conducted with a computer science graduate class of 11 students, who were given an *iPod Touch*, an *iPad*, and an *iMac* to use as their own for the semester. The *iMac* was endowed with a touch overlay to enable touch interaction comparable to the *iPod Touch* and *iPad*. The rationale for disseminating devices of various form factors was to study how the students use the devices to complete a semester assignment (in teams of three), which consisted of researching and writing a report on the field of Physical Computing. The class was held in our research center, which contains large display screens spread in meeting rooms. All students had constant access to the building, and could use their devices in conjunction with the large displays, and other laptops and desktops that they own for the assignment. They could also use the devices freely for any other purposes. Data was collected about the students' behaviors and 'strategies of use', as well as their attitudes toward and perceptions of the devices and processes through pre- and post-interviews, and observations.

IV. Study Findings

The fundamental activities that were involved in the overall process followed those specified by Umapathy [11] for collaborative sensemaking: construction and sharing of

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knowledge; collaborative development of shared knowledge; development of shared situation awareness and understanding; and communication, coordination and collaboration that support all the other activities. Across these stages and irrespective of students' prior experience with the particular devices, we found that some of the devices were never truly integrated into the students' personal sensemaking process, in particular the *iPod Touch*, the *iMac* and the large displays.

The *iPad* was somewhat integrated into the sensemaking process but to a limited extent. It was generally useful for opportunistic information foraging and for looking up only information that could be easily remembered, e.g. participants read webpages on the *iPad* only to get an overall understanding of what people think about the subject generally. The *iPad* was extensively used as well for stand-alone and transient purposes (e.g. social applications, entertainment). When notes were taken on the native note-taking application, most students reported that they stayed on the device. The *iPad* was then used as a secondary display whenever access to the notes was needed again in other contexts.

Strategies for self-sharing of information (transferring own information across different personal devices) were all through online services and cloud computing. No physical strategies, e.g. cable syncing, were used. Strategies included using *Evernote*, *Dropbox*, *Googledocs*, emailing to their own email addresses, and re-searching through search engines on another device for information found on a first device.

The difficulty to multi-task on the *iPad* was a key barrier to the use of the device for work or assignment-related purposes. While foraging for information for instance, often the students required many applications to be opened simultaneously (e.g. multi-tabbed browser, PDF reader, word document, email application). They found switching between applications on the *iPad* to be very laborious and "annoying" over extended time. At the same time, the fact that on the *iPad*, the application takes up the whole screen real estate was perceived as being beneficial to direct attention, focus and thinking. Students pointed out that this gave them the feeling that "it's the only thing that exists on the *iPad for this purpose*". On the laptop however, there is a "70-80% of surfing the Internet", e.g., while working in an application.

V. Discussion

Based on study results and theoretical underpinnings on physicality, we uncovered five main themes that relate to how devices may mediate students' thinking processes:

Theme 1: Objectification of information

We advance the concept of 'objectification' of information. Thought processes seemed to be most effective when students are able to directly, quickly and solely focus attention on the material being handled (e.g. a particular document, website), and use this material to further thinking. An illustrative scenario may be when faced with the need to retrieve a specific diagram, one can think purely of the diagram content itself and not of how to access the diagram by going to a particular folder and sub-folder first. In our study, we saw that this objectified type of thinking (as opposed to the more 'procedural' type) can be supported by devices characterized by transparency of interaction and purposeful

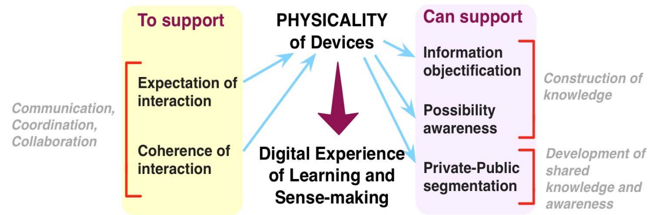

Figure 1. Role of the physicality of devices in the educational process

or dedicated use. The chief example would be the *iPad*, whose form factor and application-based model provide a constrained yet liberating environment in terms of freedom from distractions and converging object thinking through its default full screen use. Using Vygotsky's [12] terminology, with the *iPad*, what would otherwise have been just pixels on a screen become more easily a 'material carrier' of particular signs, facilitating internalization and thus allowing thinking to proceed through the medium.

Theme 2: Immediate awareness of possibilities

Possessing a device does not necessarily lead to its use and appropriation as support for work processes. Students have to be 'aware' of tools and their capability to aid particular tasks right in the moment. In Heidegger's terms, to be integrated into a learning workflow, devices need to move away from the state of being 'present-at-hand', neutrally just being there, to having a perceived significance as to their usefulness for tasks. We argue that the physicality of devices needs to be endowed with affordances that can be *perceived* by the learner to support sense-making tasks and processes.

Theme 3: Expectation of interaction

Many breakdowns in the use of multiple devices during our study occurred due to a lack of easy interaction among the separate entities: the nature of the work that can be done on the *iPad* was perceived as being distinct from that which is done on the laptop. Without a way for the students to move work done (e.g. information/picture found, document partly written, references typed) from one device to another for the ease of integration, sensemaking is hindered. In the paper world, a scrap piece of paper on which notes have been scribbled can be simply and effortlessly tacked in a notebook, and information in the notebook and on the paper scrap can then easily be used in tandem. Our experience of using tools in the world to make sense of information cannot be singular and isolated. Current strategies used by students to bridge this interaction gap among their devices are mostly ad-hoc in nature, and constructed with resources currently available (e.g. access to Internet for email). We posit that this inability for students to expect that devices will interact may guide decisions on the use of devices for certain tasks and even deter completely from device appropriation.

Theme 4: Coherence of interaction

Cross-device interaction must be accompanied with a coherent experience in use. Varying features, incompatibilities and illogical procedure flow in the interaction from the student's point-of-view increases the learning curve during switches between devices. We are not advocating that the interface should necessarily be identical or similar on all devices. Applications that currently allow interaction among different devices through cloud computing follow such a one-framework model. Instead, the particular physicality of each device (each is arguably more amenable for some tasks than others) can be used to dictate the design of features and interaction needed to provide support for processes vertically throughout the knowledge construction workflow. Making full use of the totality of all the different devices concurrently thus will create a wholesome learning experience, instead of jarring staccato advancements in work each time.

Theme 5: Territorialization of technology spaces

Many have highlighted the importance of space and place in collaborative work systems. During scheduled collocated work sessions in our study, the appropriation of personal and shared spaces was through a segmentation of technology 'surfaces'. Although mostly stable, the segmentation varied depending on form factor, accessibility, changing discussion content and varying spatial layout. E.g. although the laptop and/or tablet were typically used as private spaces when brought in meetings, they were at times also used to physically share information. Whether this dual use of the same technology 'surface' as both private and public space is detrimental to sensemaking remains to be investigated.

A Model of The Role of Physicality in Education

Simply giving technological devices does not by default translate to beneficial changes in the educational process. Although some benefits came in the use of new educational/productivity software on the *iPad*, the very physicality and interaction effects of devices mediated how students used digitality to construct knowledge and make sense of information to complete the assignment. Figure 1 shows a model of the role of physicality of devices with regards to support requirements, effects on collaborative sense-making activities, and importance of a cohesive learning experience.

We posit that two key features are needed to fully realize the potential use of all the different devices in our milieu: an *expectation of interaction* and a *coherence of interaction* across devices. These act as an underlying buttress in terms of communication, coordination and collaboration for other activities in collaborative sensemaking described at the beginning of Section IV. We identified that physicality in turn can affect thought processes in three ways: through encouraging or discouraging objectification of information, moderating awareness of task and use possibilities, and steering choices in the segmentation of technology 'surfaces' into private and public spheres. Information objectification and possibility awareness can positively change the way information is regarded, directing attention to the most effective device for particular tasks, and focusing attention during the use of a device by turning it into not only a 'carrier' of thought but also a support for the actual process of thinking.

Each device that populates our technological environment is perceived to have more of a public or private connotation attached to it. Within one's own suite of devices, the same public-private attribution is done so that when a 'private' device is used to be a 'public' space, the switch is quick and temporary, and sometimes even accompanied by a certain discomfort. The support of easy cross-device interaction may help to attenuate this discomfort by keeping the segmentation stable during collocated collaborative work.

Based on our study, we argue that for digital devices to support the whole learning/sensemaking process and to allow students to construct their own knowledge, devices need to be able to work in concert and encourage appropriation. To take the analogy of the paper world that we live in, each piece of paper, pen, bookmark, highlighter that we appropriate to support our learning experience has been designed to fit into and contribute to that particular paper ecology. The framework that we presented identifies requirements that can potentially allow computational devices to form a digital ecology that is counterpart to the paper ecology, and affordances through which the digital devices, by their embodied nature, work through to support the sensemaking workflow.

VI. Conclusion

That technological devices are now ubiquitous in education is a fact for both institutions and the individual learner. Much research that investigates the benefits of those devices for learning takes the point of view of digitality. We question instead how the physicality of devices and the effects of interaction that it brings affect processes involved in learning. We argue that to achieve a coherent and substantive experience of learning with digital devices, there is a need to design new interaction affordances that will support a digital ecology. Further research is needed to specify the exact ecology architecture that can effectively motivate full use and appropriation of devices among learners.

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