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Attention Management as a Fundamental Aspect of 21st Century Technology Literacy: A Research Agenda

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Abstract
The purpose of this paper is to raise awareness about the importance of attention in today's stimulus-rich environment and to argue for attention management as a fundamental technology literacy skill that needs to be integrated in technology and engineering education. The paper presents evidence about the costs of distraction and multitasking, reviews theoretical frameworks that explain the functioning of human attention and the possibility to train it, and introduces an empowering perspective for enabling students to master their own attention. A simple method for attention training is presented and data that validates the concept of integrating attention training into higher education is presented.

Introduction

We live in a culture of distraction. Information technology and online communication bring more streams of information than ever to our fingertips and compete for our attention. Perhaps nowhere else is this as true as in the higher education classroom, where technology is actively used - whether invited by educators or not. In any given class, educators compete for students' attention with Facebook and text messages as well as sanctioned educational technologies like slide presentations and educational software. Research shows that humans' cognitive capacities are limited; that competing streams of information, multitasking and task switching present serious challenges that may jeopardize learning and task performance and have dire effects on culture, society, and the economy in the long term. Attention management – the ability to direct attention volitionally to certain stimuli and away from others – is becoming a critical skill in today's technology and stimulus-rich classrooms, offices and lives. **How do we prepare students to manage, distribute, and assign attention?** The purpose of this paper is to bring awareness to the importance of attention self-regulation and discuss it as a fundamental technology literacy skill. The argument presented here is that attention training should be considered a fundamental part of technology literacy and should be integrated in higher education. The paper begins with a discussion of technological competency that shows tool operation is a necessary, but insufficient aspect. It then discusses the challenges posed to human attention by today's information and stimulus-rich environment, and then proceeds to review theoretical explanations from the fields of psychology and education as well as possible solutions. Attempts to implement attention management training in higher education are discussed, and data is presented about students' acceptance of this type of education. Finally, the paper outlines directions for a research agenda about attention education.

Technological Competency: Beyond Tool Operation

The Center for Public Education report "Defining a 21st Century Education" identifies technology as the primary driver of changes in our society and names technology literacy as one of the most important literacies of our age [1]. The strategic importance of technology is recognized by the National Science Foundation, which considers technology essential, not optional, for STEM education [2] and recognizes that for the first time in history, "'online' will be

the dominant operating mode for individuals" [3]. The National Science Foundation and the National Academy of Engineering have recognized the need to teach and learn with technology (cyberinfrastructure) and to acquire technological competencies as a top priority for U.S. STEM education and workforce development [3-5]. The "Cyberinfrastructure for education and learning for the future: A vision and research agenda" report to the National Science Foundation argues that technology-based education must extend to all areas and settings of life, both formal and informal [6]. At the same time, nationally recognized experts agree that the integration of technology in education is not without dangers: "as innovations multiply, so do dangers" [7]. Technological competencies include not only the skills needed to operate information technology, but also critical consideration of "privacy, social, cultural, ethical, and ownership issues associated with increasing use of cyberinfrastructure for learning, research, and scholarship" [3]. Achieving successful results such as scientific and engineering innovation with technology requires more than operating tools: it demands "an ability to understand tools and media critically" [8]. Experts agree that educational institutions need to "help young people learn how to use information technology more responsibly, reflectively, and effectively in different areas of life" [1]. These reports identify a strategic need to extend technological competencies beyond tool operation by building fundamental knowledge and skills about the management of attentional resources with respect to information technology use. But, does today's technology-rich engineering education address this strategic need?

The Technology Classroom

In this discussion, the *technology classroom* is defined as formal higher education settings where technology and engineering disciplines are taught, where technology is present in the classroom and is used primarily for educational purposes, but possibly for non-education related tasks as well. In engineering and technology disciplines, technology often is both the means and goal of instruction and, therefore, it is likely to be used in the classroom to a larger extent than in other disciplines. Trends in higher education have pushed towards the inclusion of more and more technologies in the classroom, partly as a way to address the strategic needs as discussed in the previous section. The use of technology in the higher education classroom is associated with learning benefits and positive student perceptions, but is not without drawbacks. Distraction costs resulting from the use of multiple technologies have been shown to negatively impact learning.

One documented **benefit** of using technology in the classroom is enabling active learning and student engagement [9-15]. A second benefit is increasing students' motivation to learn [16-20]. Increased student satisfaction is a third documented benefit of using information technology in the classroom [21-23]. However, several studies found that the use of information technology in the classroom is not entirely beneficial, because it comes with **associated distraction costs** [9,24]. A number of studies document **negative effects** of information technology on learning, and explain that distraction and divided attention account for these effects [25-31].

The unsanctioned use of technology by students in the classroom could be easily dismissed as misbehavior. However, recent findings from cognitive neuroscience show that our information-rich lifestyle may lead to information addiction [32] and in turn, to a type of induced ADD referred to as attention deficit trait [33]. The consequences of these attention disorders are dire: inability to attain and sustain deep focus and the state of flow [34], which are both directly related to learning, problem solving, creativity, productivity, and even life satisfaction [35,36]. Some

have linked the inability to control and focus attention to decreases in intelligence [37,38] and the coming of a new dark age [39].

These concerns are not completely unfounded. Research has documented the costs of disruptions, interruptions and multitasking in educational, workplace and experimental settings. Disruptions caused by incoming new information such as a new message alert or even a low battery warning have been shown to slow task performance and increase errors [40-43]. Interrupting one task to perform another causes delays in resuming the initial task and lowers performance [44-53]. Multitasking is also associated with decreased overall performance [54-57].

The issue of distraction in the classroom has caught the attention of the popular press and the general public. Several newspaper articles have highlighted concern about distraction caused by information technology in the classroom [58-64] and some even call for the need to police it [61]. Indeed, some universities such as the University of Kansas, University of Pennsylvania, Brigham Young University, Harvard, Bentley College and The University of Michigan Law School have initiated efforts to block or ban laptop use in the classroom [62,65-67]. In one extreme case, a professor at American University in Washington was arrested after slamming a student's laptop shut and hurting the student's fingers. The student was using Facebook during class time [68].

Banning information technology from the classroom is one extreme solution. Advocated by some, especially in law schools [69], this solution is not feasible or desirable in engineering and technology education. Instead, engineering education must empower students to use technology "responsibly, reflectively, and effectively" [1]. More moderate solutions include the use of deliberate computing [70], which guides students' use of technology by telling them when to use laptops, when to shut them down, and provides specific directions for engaging with lecture material [71-73].

The problem of distractions caused by multitasking, task-switching and interruptions has been an important issue in human-computer interaction in the past decade [74]. Several researchers, both from academia and industry, have tried to create interface solutions for personal computers that minimize the costs of interruptions and distractions e.g. [75,76-79]. These interface innovations help to a certain extent, but only in the limited desktop environment of the application suite they were designed for. They cannot help computer users manage multiple streams of information coming from multiple sources and multiple devices. In a typical technology classroom, a student may be exposed to the following sources of information: instructor slides, instructor voice, computer, phone – the latter two capable of supporting several streams of information each. No external technology or agency can manage an individual's attention across so many distributed stimuli. All solutions discussed so far suffer from the same limitation: **They attempt to control attention externally instead of empowering individuals to manage their own attention**. This paper adopts a radically different approach in that it argues for empowering students and shifts the locus of attentional control from external to internal. The long-term vision of the research agenda proposed here is to generate fundamental knowledge and strategies about how engineering education can help individuals learn to control and manage their own cognitive and attentional resources in order to use information technology reflectively and optimally. In order to do so, it is important to establish a basic common understanding of the psychological mechanisms at the center of this argument. Cognitive load theory, attention theory, and

specifically the training of executive attention inform this discussion.

Cognitive load theory

Cognitive load theory has emerged at the intersection of psychology, education, and communication. Cognitive load theory explains the cognitive processes involved in learning. Even though there are several variations of cognitive load theory, which will be discussed next, all models are based on the same assumption: the amount of cognitive resources a person can devote to a task at a given time is limited and finite. Because of limited and finite resources, cognition can experience overload, which causes the process to break down and interferes with message processing, understanding, memory, and learning [80]. In education, cognitive load theory informs the creation of instructional materials that reduce unnecessary cognitive effort and therefore facilitate learning [81-84]. In communication studies, cognitive load theory informs message design so as to facilitate message processing – for example, in advertising or public awareness campaigns [85,86].

Attention is the first and essential step in cognitive load models. For example, Mayer & Moreno's [83] model of multimedia learning has three steps: (1) selecting information, which involves deciding where to direct attention; (2) organizing material into a coherent mental structure; and (3) integrating new material with existing knowledge. Lang's [85] model begins with (1) sensory perception and continues with (2) selection of sensory data through attention processes, followed by (3) storing new information by linking it with existing memories and (4) retrieval of stored information. Of course, sensory perception – the ability to see and hear a message – is essential to learning. This project assumes that users do not have insurmountable physical limitations of sensory perception. Given operational levels of sensory perception, the first bottleneck where learning can break down is selection of stimuli to attend to – in other words, attention. As established before, in the technology classroom, there are more stimuli than ever before to choose from, which places unprecedented demands on students' attention.

Attention Theory

Basic attention theory distinguishes between top-down (endogenous) and bottom-up (exogenous) attention [87]. Bottom-up attention is focused automatically during exposure to salient stimuli. For example, a moving item in an otherwise still scene is a salient stimulus that will "grab" – that is, focus, bottom-up attention. Top-down attention can be controlled volitionally [88]. The volitional control of top-down attention is of central interest to this project.

Posner [89] identified three separate attention systems: alerting, orienting, and executive. This tri-fold model of attention has been consistently confirmed by subsequent research [90]. Alerting attention governs alertness and vigilance – the capacity to sustain attention and be ready to respond to stimuli. It is crucial in activities such as driving, piloting a plane, or monitoring a radar screen as air traffic controllers do [90]. Orienting attention is the capacity to shift attentional focus from one stimulus to another. It is often explained through an analogy to a flashlight beam that can be shifted from one item to the other. It is involved in scanning the environment and selecting stimuli and it can be either endogenous (top-down, controlled volitionally) or exogenous (bottom-up, captured by a stimulus) [90]. The third attention system and the one of most interest here is executive attention. Executive attention governs the effortful control of attention, such as the decision to ignore some stimuli and focus on others. Some researchers consider all top-down attention executive attention, but executive attention is a more complex system that

also includes self-regulation (such as the type needed when following a healthy diet or regulating the amount of time spent on Facebook), planning, and decision making [91-93].

Executive attention can be trained

Ground-breaking research conducted by Michael Posner and colleagues has demonstrated that executive attention can be trained in as little as five days [94]. Methods for attention training include interactive computer-based exercises for children and techniques for adults that do not require the use of technology. Several research studies have documented the effectiveness of attentional training in children [93,95-97] and adults [98,99]. Moreover, attentional training has been shown to improve the symptoms of Attention Deficit and Hyperactivity Disorder (ADHD) in children [100,101] and adults [102].

Researchers who work in the field of attentional control, like Michael Posner and Leanne Tamm, argue for the **need to integrate attentional control in education**. "Kids are always told to pay attention, but they don't know what that means" Tamm, cited in [39]. Because of the intense demands on human attention of information technologies, attention management should be included as a fundamental technological competency and taught as a technology literacy skill.

Some educators have already begun teaching attention regulation in higher education courses. Their efforts are discussed next.

Contemplative practices in higher education

The Center for Contemplative Mind in Society has spearheaded the inclusion of attention training techniques in education. A book published in December 2013 [103] explains the methods used to teach attention regulation and aims to empower educators to adopt and teach them to students. The authors present arguments about the importance of learning how to self-regulate attention and explains that this can be facilitated by the sustained practice of introspective and contemplative activities such as mindfulness meditation, contemplative reading writing, and listening, mindful movement, and compassion practices. They present research about the effectiveness of mindful meditation and related practices for regulating attention, emotions, stress management, etc. Even though mindfulness meditation appears an effective way to train attention self-regulation, it poses several challenges. First of all, mindfulness meditation and other contemplative practices originate from various spiritual traditions. They are most readily associated with Buddhism, but all major religions mention some types of contemplative practices, according to Barbezat & Bush (2013). The inclusion of such contemplative practices in secular higher education requires removing them from their original context and as such they lose some of their meaning and power. At the same time, even though the techniques themselves do not rest on assumptions of faith and divinity, their association with religious traditions raise a host of issues most educators are not prepared or willing to deal with. A second challenge is that these contemplative practices require extensive first-hand experience before an educator is able or ready to share them with students. This makes the solution not scalable, since it is not realistic to assume that mass numbers of technology and engineering educators will take up and sustain mindfulness meditation practice. Barbezat and Bush (2013) also point out a third and related challenge: That, by nature of their introspective and spiritual nature, contemplative practices might raise complex questions about the nature of the mind and self that most educators are not prepared to address. For example, a relatively simple mindfulness practice instructs the practitioner to attempt to focus one's mind on one point and not get carried away in thought,

even though thoughts might arise. Naturally, the mind cannot be so easily controlled and thoughts arise even without volition. This phenomenon raises questions about intentionality, volition, thinking, and control, as well as the nature of the self and the mind: Whose thoughts are these, and why do they arise without my intention?

These challenges suggest that even though contemplative practices might be effective in teaching the self-regulation of attention, they are difficult and problematic to implement at large scale. Better solutions are needed that can address this area of strategic need.

So far, this paper has argued that technological competency includes much more than tool operation. One of the many aspects of ethical, responsible and creative technology use is the ability to control and distribute attention. Information technologies pose tremendous challenges to human attention and place tremendous requirements upon it. Therefore, attention is a precious resource that needs to be managed carefully. Cognitive theories show that attention is a major bottleneck that can affect learning, creativity and productivity. Research also shows that, fortunately, attention can be trained. The argument presented here is that attention training should be considered a fundamental part of technology literacy and should be integrated in higher education. However, more research is needed in order to create feasible and scalable pedagogical solutions that can enable large numbers of educators to help students learn how to regulate their own attention. This paper argues that the training of attention should be included in the engineering education research landscape and proposes some questions that could inform a research agenda:

- What are feasible and scalable ways to integrate education about attention self-regulation in technology and engineering courses?
- What are educators and students' attitudes about the need to learn how to self-regulate attention?
- What are the opportunities and barriers to acceptance of the need to learn attention self-regulation?
- What are opportunities and barriers to acceptance of specific techniques for learning attention self-regulation?
- What are short and long-term impacts on learning of attention self-regulation practices?

In order to provide some leverage for the research agenda drafted here, the remainder of the paper presents the results of a small study that aimed to capture graduate students' attitudes and acceptance levels for integrating attention management into higher education. Graduate students are in the double role of both student and educator, as many of them hold teaching assistantships and/or aim to become professors after graduation. Thus, their dual perspective was considered advantageous for validating the basic idea of integrating attention training in higher education.

The graduate students were enrolled in a PhD level technology seminar that included, among other topics, the issue of attention and distraction caused by the recent growth of information technologies and social media. The students were exposed to arguments similar to the ones presented in this paper, about the demands placed on attention by information technologies, the costs of multitasking and distraction, and some basic attention theory. A brief attention training exercise was introduced in class, where students were prompted to keep their minds focused on a

single object for a period of two minutes. The students were then encouraged to experiment on their own time with attention regulation and the mindful use of information technology and to reflect on their experiences. After the semester was over, the instructor sought IRB approval to send an online questionnaire to the students enrolled in the class in order to understand how they received the information about attention and distraction, whether they thought it would be useful for something like this to be included in other courses, and whether they would include it in the courses they teach. Nine of the twelve students enrolled in the course answered the questionnaire. Four were studying for their M.S. and five towards their Ph.D. degrees. Six of the students were female and three were male. Their ages were split between 20s (5 students) and 30s (4 students). Five students were international and four were domestic.

Overall, the students reported finding it both interesting and useful to learn about how their attention works and about the dangers of distractions. They elaborated that learning about attention and distraction prompted them to be more reflective with their technology use in other areas of life and even pass this knowledge on to their own students.

All but one of the students agreed that learning about attention and distraction motivated them to reflect more on their technology use, but only four of the students reported being motivated to actually change their patterns of technology use. Students explained that even though they thought about these issues on a daily basis, they found it difficult to actually change behavior patterns.

All students agreed that education about attention and distraction should be integrated in higher education, at both the undergraduate and graduate levels. They also agreed that knowledge about attention and distraction in the context of technology use should be a basic skill for everyone who uses information technology heavily. However, agreement was split on the idea of integrating basic attention training techniques such as focusing on one point for a few minutes in courses. Even though there was no disagreement, two students remained neutral on the issue and overall, agreement with this idea was not as strong as with the previous ones. The graduate students explained that they, too, believed that the ability to control the focus of one's attention is a basic life skill in today's environment, similar to critical thinking skills, and attention training could be a skill that would benefit students life-long.

When asked at what points of their education students should be taught about attention management, the respondents indicated that the earlier, the better. They suggested a dedicated course or sections in introductory courses at both the undergraduate and graduate levels. They also suggested sustained practice, since training takes a while to become effective. They pointed out that while theory about how attention works is important to understand, this area needs sustained practice. One student noted that the spiritual under-tones of attention training practices can be of concern, and that it would be important to address the research and evidence before engaging in such exercises in order to overcome possible initial barriers.

Overall, data from a small group of graduate students who were exposed to mostly the theory behind the need to understand and manage their own attention indicates strong support for the concept of integrating attention training in higher education. However, specific and feasible methods for doing so effectively still remain to be proposed and evaluated. Before developing such methods, it is important to engage in a conversation about their need and appropriateness.

This paper is intended to inform and stimulate such a conversation.

Conclusion

The purpose of this paper was to introduce the training of attention self-regulation as a topic of discussion and research in engineering education. Attention self-regulation should be a fundamental technological competency and should be trained as part of technology and engineering studies. Extensive literature was reviewed that documented the need for including attention management training in higher education. Findings from neuroscience and psychology were discussed, showing that executive attention can be trained. The challenge pointed out in this paper was not about the conceptual need to train attention management, but about the practical ways of doing so. So far, attempts to teach attention management have drawn heavily upon spiritual and religious traditions and as such they are problematic to implement at large scale. A research agenda was proposed, that would include attention management as a topic of discussion and research in engineering education. An initial series of questions was outlined, that can provide a starting point for the conversation. Additionally, this paper presented initial data about graduate students' perceptions of the desirability and utility of including attention management training in higher education.

The problem of integrating attention management training in technology and engineering education is a broad and complex one. It cannot be solved in one attempt. The purpose of this paper was not as much to solve the problem, as to present it to the community for discussion and further investigation, and to argue that attention management is a topic worthy of engineering education researchers' attention.

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