GOOGLE IT: CRITICAL THINKING AND PROBLEM SOLVING IN THE INTERNET AGE

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Abstract

This paper addresses the relationship between technology use and the level of critical thinking and problem solving of university students. We draw on sensemaking research and argue that the majority of educational technologies available facilitate information acquisition but neglect the construction of knowledge and problem solving. Meanwhile the ubiquity and convenience of information acquisition tools encourages users, particularly less-experienced ones such as university students, to rely on information gathering as opposed to problem solving and knowledge acquisition. Drawing on sensemaking perspectives, we suggest there is a need for technology-based assistance for higher-level information processing practices.

Keywords: education, technology, problem-solving, sensemaking

1 INTRODUCTION

The rapid advances in the use of digital technologies and the Internet in particular, have initiated significant debate on the way these technologies are changing our mental processes [8].There is a growing understanding that while our technologies are the result of our thought process and mental abilities, they in turn affect how we think [42]. There is an immediate need in educational circles to understand this phenomenon and adjust pedagogical methods accordingly.

Among other things, university level education is expected to facilitate the development of critical thinking and problem solving skills [11]. It is expected that graduates, when faced with a problem will be able to “find a solution”. While educators hope to help student learn how to “think about a solution”, various technological resources are becoming increasingly available that help students “search for a solution”. The Commission on the Future of Higher Education (a 19-member panel of experts) states in its report [47] that they are “disturbed by evidence that the quality of student learning at U.S. colleges and universities is inadequate and, in some cases, declining” and that “employers report repeatedly that many new graduates they hire are not prepared to work, lacking the critical thinking, writing and problem-solving skills needed in today’s workplaces.” As reviewed briefly in the next section, researchers have investigated the effect of various factors on critical thinking and problem solving abilities. This has resulted in a wide range of valuable findings related to the importance and advantages of experiential learning and learning-centred education [4][45]. In this paper, we would like to draw particular attention to the link between the decline in problem solving and critical thinking abilities among university students and their use of internet-based tools for collecting information.

The ubiquity of internet search technology has made it possible for many people to solve problems to which they have no expertise on their own by searching for common solutions (e.g. phone is not responding). While this is in principle a positive outcome of the technology, in an educational setting the overreliance on search technologies may result in students’ lack of problem solving and critical thinking abilities, which may result in weaker performance when those tools are not available, and in the long term compromise creativity, adaptability, and originality. Current educational trends that rely on exploration, playful action, and open-ended tasks, may indirectly contribute to the overreliance on search technology by encouraging students to explore topics and tools of interest, as opposed to providing students with a structured foundation on which to build knowledge.

In this paper, we describe the issues arising from an overreliance on technology in the context of two different university courses in computer programming and cross-cultural management. We discuss how the ubiquity of advanced easy-to-use search and production tools was associated with lower problem solving and critical thinking abilities, while creating an illusion of learning. We found that students repeatedly relied on searching and compiling information from various online resources as opposed to establishing proper understanding of the subject matter. For example, students in the programming course assembled code samples from various sources but were less skilled at producing novel programs themselves. Likewise, in the cross-cultural management course students were able to collect information about several countries and cultures but less able to understand the meaning of these data for management practice. These findings may be part of a larger cultural trend that emphasizes acquisition of large amounts of data as opposed to transformation of information into knowledge.

We suggest that while the use of technology is in general positive and can solve many problems, it is crucial that technology is used properly to facilitate learning and the development of critical thinking and problem solving skills. We propose avenues for mitigating the possible negative impacts that overreliance on technology can have on critical thinking and problem solving skills, and discuss future research directions.

In the following section, we briefly review the academic research related to this topic. We then draw on sensemaking literature to establish a theoretical framework relating the technology use and problem solving practices. We present two examples and discuss their implications to educational technology research and practice. We close with directions for future research.

2 RELATED WORK: TECHNOLOGY IN EDUCATION

The ubiquity of Information Technology (IT) in our everyday life, particularly in the 21st century, has been the topic of many academic studies. While researchers acknowledge the positive effect of IT in many areas including education [12], the ever-increasing use of IT tools - especially the Internet - has drawn some criticism. For example, Graham and Metaxas [22] highlight the unreliability of information available on online sources, and raise concerns that users may have unjustified trust for information available online. In addition to trustworthiness, other researchers have raised concerns about the way the content is used, even when the content is of good quality. As media theorist Marshall McLuhan [29] suggests, the media is not just a channel for passing information; it actively affects the way we process information. Carr [8][9] argues that the web-based content is “a swiftly moving stream of particles” referring to abundant and frequently shallow information, and the ability to browse quickly. He quotes a writer saying “I now have almost totally lost the ability to read and absorb a longish article on the web or in print,” as an example of web users tendency to avoid studying long material (and so thinking for long periods of time). Carr also suggests that the “quick browse” approach fits the business goals of online service providers such as Google which benefit from such behaviour as opposed to leisurely reading [9].

While these and similar claims may be speculative and require experimental validation, recent studies such as one performed by University College London provide support for such claims [37]. Their study demonstrated that people using popular reference and search tools exhibited “a form of skimming activity,” hopping from one source to another and rarely returning to any source they’d already visited. They typically read no more than one or two pages of an article or book before they would “bounce” out to another site. Sometimes they’d save a long article, but there’s no evidence that they ever went back and actually read it. The authors of the study report: “It is clear that users are not reading online in the traditional sense; indeed there are signs that new forms of “reading” are emerging as users “power browse” horizontally through titles, contents pages and abstracts going for quick wins. It almost seems that they go online to avoid reading in the traditional sense.” Such studies support claims made by researchers such as Maryanne Wolf who argue that the changes in reading style will then affect the mental structures, the way we think, and “who we are” [46].

Concerns regarding the importance of education beyond information acquisition are not new, nor are they a product of information technology. For example, Piaget [33] and Kolb [25] advocated the importance of learning through experience; while Csikszentmihalyi [14] discussed the flow theory that suggests an optimal experience as one in which the person is fully immersed and engaged resulting in higher pleasure and efficiency. Since the 1950’s, researchers in cognitive theory and education have used Bloom’s taxonomies of learning [5]. In a number of landmark papers, Bloom and colleagues identified three learning domains: cognitive, affective and psychomotor. Bloom differentiates the following levels of thinking: Knowledge (facts), Comprehension (understand meanings), Application (apply to new situations), Analysis (see organization and patterns), Synthesis (generalize, create new ideas) and Evaluation (assess value of evidence).

Subsequently, Anderson et al. [3] identified four categories of knowledge within the cognitive domain, each requiring different kinds of learning: factual, conceptual, procedural, and meta-cognitive. Ackoff [1], on the other hand, argued for a distinction between Data (facts), Information (processed data) and Knowledge which is a higher level mental model based on understanding the relationships and patterns. Others argue that application, analysis, synthesis and evaluation in Bloom's model are processes involved in problem solving [13][35].

Despite different terminology and categorizations in the learning processes, there is a widespread agreement that there are different types of thinking processes and mental models required for different practices. While information gathering has its place, creative problem solving requires more sophisticated mental models and learning practices. In addition, various experiential learning approaches presuppose that student will be able to make sense of their experience and transform it into knowledge [25].

3 THEORETICAL FRAMEWORK: SENSEMAKING

In this paper we focus on understanding the role of educational technology in facilitating critical thinking and problem solving skills. We draw on sensemaking literature to understand the process through which students transform information and experience into knowledge. Sensemaking is a growing field of research focusing on understanding the process by which people give meaning to experience. While sensemaking research span several disciplines, we draw heavily on research on sensemaking in organizational studies, especially the work of Karl Weick and associates [43][44]. Through sensemaking individuals are able to organize their experiences, understand what they think, and predict future events and outcomes [43]. Sensemaking may be instigated by a discrepancy [31] or a surprise [27] and involves asking, "What's going on here?" and then "What should I do?" [44]. Sensemaking results in learning [15] or modified schema [23]. Learning and new or modified schema then influence which events or discrepancies are noticed and how they are interpreted, feeding the cycle of ongoing sensemaking [43].

While everyone "sensemakes" in a continual basis, expertise plays a role in influencing what is noticed and what is the subject of sensemaking. What we know influences what we notice, how we interpret what we notice, and how we are able to make sense of things [28]. As a result, novices and experts will think differently about a subject.

Lundberg [28] proposes three levels of practice in managerial sensemaking which parallels students' sensemaking in various fields: naïve practice, systematic practice and sophisticated practice. In naive practice individuals notice symptoms but their problem solving is focused on fixing the symptoms, usually by relying on what is familiar. In systematic practice, individuals can identify the problem and adopt best practices and applied research to solve it. Finally, in sophisticated practice individuals are able to regular assess their performance and refine their practice according to contexts and contingencies. We build on Lundberg's framework [28] to explore the role of educational technology in three stages of problem solving practices, as illustrated in Table 1.

	Naïve	**Systematic**	**Sophisticated**
Mental Model	Imitation	Simple causal models	Complex associations
Level of Understanding	Noticing symptoms	Identifying problems	Proactively exploring application of knowledge
Distinguishing Skills	Searching for solutions that apply to similar symptoms	Searching for solutions to problems	Creating new solutions or identifying new applications of knowledge
Expected role of educational technology	Facilitating information acquisition	Facilitating creation of mental models, problem identification and customizing solutions	Facilitating idea development, exploration, contextualization and solution development

Table 1. Problem Solving Practices and the Role of Technology

As described in Table 1, technology (particularly online tools) facilitates the collection of information characteristic of naïve practices. As students approach novel topics of study information technologies facilitate the collection of information that will form the basis of a more sophisticated mental model later on. However, if we are not careful in how we structure our learning experiences, some students may over rely on information technologies for problem solving and not develop the mental models required to advance to more sophisticated levels of thinking and practice.

Continuous advancement has been made in development of intelligent systems to identify patterns on data and perform thinking and sensemaking similar to human brain, at many levels and in many situations [38][21]. There are many successful systems and products in areas of artificial intelligence and data mining that rely on analysis of data and making intelligent decisions. But it is our contention that it is important for students to acquire the skills to identify patterns and problems and create novel solutions themselves. This requires the development of sophisticated complex mental models in a field of study which should be assisted by the technology. A sophisticated mental model must be formed in the mind of the learner through sensemaking activities, it can't be transferred as pieces of information that are memorized.

We build on the work of Bruce et al. [7] who categorize educational technology into Inquiry, Communication, Construction and Expression to explore their role in learning and sensemaking. We expand on their model to better reflect the more recent prominence of content management and simulation tools, as described in Table 2.

Type of Technology	**Examples**	**Learning Outcome**
Search engines, databases and online forums	Google Search, Wikipedia	Finding information
Content management	BlackBoard, Moodle	Accessing information
Content creation	Photoshop, MS Office	Creating content
Communication	Skype, Gmail	Collaboration and brainstorming
Simulations and educational games	Various programs	Experiential learning context

Table 2. Categories of Educational Technologies

While content creation, communication and simulation tools are critical for educational activities, they do not directly aim at helping with learning and problem solving practices. Instead, they provide content and context for learning activities. Search, databases and online forums are directly aimed at collecting information, an activity typical of naive thinkers in a field. These tools are powerful in providing the informational background for learning on a domain, and remain necessary at later stages of learning and problem solving. However,, there is a risk that, in the absence of other tools aimed at forming and applying knowledge, the convenience and popularity of these tools will encourage students to use data collection tools as a way of solving problems. This will result in lack of practice in higher levels of critical thinking leading to low performance when facing new and uncertain situations.

As we can see in the examples presented below, there is a need for educational technology that is aimed directly at assisting the sensemaking process by helping students to identify patterns, develop mental models, and reflect on experiences. While there are simple journals and note-taking tools, the advances in technology have created the potential to develop more intelligent tools to assist in the reflection and knowledge formation process, and help explore new domains. Typical tasks among the systematic and sophisticated practices that can be assisted using technology include but are not limited to:

- Problem setting: The process of identifying problems [43]
- Reflection: Self-interpretation of experiences and understanding what they mean at a personal level [6]
- Structure: Development of representational schemas that best fit the evidence and provide a basis for understanding the data [34]
- Application and Transfer: Applying mental models and learned theories into new domains

We demonstrate the need for tools to aid sensemaking through two examples, presented below. While cross-cultural management and computer programming are distinctively separate domains, in both cases we can see how students may use ubiquitous information collection methods to solve problem without proper sensemaking. The students may develop strong skills for search and acquisition of information from online sources, and in a few cases successfully solve problems by copying a solution that deals with similar symptoms, but they will lack a proper understanding and creative ability to deal with new and ambiguous circumstances.

4 EXAMPLES

4.1 Cross-Cultural Management

In today's multicultural workplaces and globalized world, performance often depends on successfully interacting with people from other cultures. We refer to the set of skills required to succeed in multicultural environments as intercultural competence. Intercultural competence takes into account workplace diversity, requires constant problem solving as cross-cultural situations are not easily labeled for solution, critical thinking, and the constant re-evaluation of one's own thinking and assumptions.

Much cross-cultural training and development is based on the transfer of country and cultural information, which often relies on simplified cultural dimensions. Cross-cultural educators have criticized this type of training arguing that it does not accurately represent reality and may lead to stereotypical thinking [32][19][20]. Learning the dos and don'ts of specific cultures are of little help because each cross-cultural encounter is unique, involves different people, contexts, and dynamics, and require different actions and reactions. As a result, intercultural competence is not developed through information acquisition. There is a growing sense that intercultural competence is best developed through experience [20][39][40][41][30], provided learners are able to make sense of those experiences through reflection [17][18][30].

A typical cross-cultural management course would provide frameworks for the understanding of culture and its influence on behavior, request students to study a culture in depth, and provide recommendations on how to deal with individuals and organizations in their focal culture of study. Our experience shows that while students are able to assemble massive amounts of cultural information from various websites (often of questionable quality) they fall short in making sense of that information and developing an understanding of culture beyond factual and stereotypical information.

Their comfort with the use of technology makes them have an illusion of learning because they are able to quickly collect a wide range of factual information and ignore the need for deeper thinking required to make sense of the information and develop sophisticated mental models of culture and behaviour.

4.2 Computer Programming

Computer programming courses have been the subject of many research works [36]. While there have been many approaches to teach and learn programming skills, the activities that students can perform in order to develop these skills (and prepare for exams) can be grouped into six main categories (not including required assignments):

1. Reading provided text material
2. Reviewing provided examples
3. Finding new text or examples to read/review
4. Re-doing the provided examples as practice
5. Writing the code for given sample problems
6. Finding new problems to solve (new code to write)

These activities can include various combinations of the three stages of problem solving practices (Table 1). While the finding and reading text and sample code are clearly information collection, they may include knowledge formation as well. On the other hand, finding new problems and developing new code can potentially be good cases for applying knowledge in a creative way. These are in fact activities that will result in real understanding of computer programming.

While stronger students cover all these activities in their studies, our observation over the past 10 years have shown the increasing occurrence of two behaviours. Firstly, a large group of students limit their work to finding and reading text and sample code. It is worth noting that there is a clear correlation between this behaviour and lower grades. This behaviour while very important is not directly related to the topic of this paper.

The second important observation is that students who do engage in more hands-on activities such as finding new problems and writing code for them, and in general any actual programming task, tend to use online resources to find solution. This is encouraged and amplified by the presence of many online forums such as Stack Overflow and convenience of searching for sample code.

The common practice in teaching programming has been to use a combination of the above mentioned categories of learning activities. This results in students not developing problem solving skills appropriate for systematic and sophisticated practices. While dependence on more hands-on and experiential methods [36][2] do encourage a change in favour of systematic and sophisticated practices, the reliance on search and information collection can significantly reduce the advantages by developing imitation-style thinking. Considering the familiarity and attachment of younger generations to various technological assistive tools, it is important to develop educational tools that help them make sense of programming concepts and form more complex mental models. Although some examples of such tools have been developed and tested [16], they are usually limited to a context for practice or a graphical environment to simplify the tasks for beginners. These tools are not aimed at developing complex mental models, reflecting on experiences, and establishing complex associations.

5 CONCLUSION

We have discussed the relationship between educational technology and problem solving practices based on our own experience teaching computer programming and cross-cultural management courses. Drawing on sensemaking perspectives, we have argued that the overreliance on online information collection tools can result in deficiencies in problem solving skills. While there are many tools available for various educational purposes (from content creation to simulation), we suggest that future research focus on the development and validation of educational technologies aimed at helping students through the process of sensemaking. We do not support any claims that online search and information acquisition tools “make us stupid”, but our observation suggests that we may do so ourselves through the misuse of such tools.

While this paper is based on extensive observation, it is not based on a formal research study. Our arguments in support of developing new tools that help in the sensemaking process are preliminary and lack details of what functionality these tools should have and how they can be achieved. Further research is required to understand students’ behaviour with regards to information acquisition and sensemaking. Our next step in this research is to develop tools to assist in sensemaking practices such as problem setting, reflection, and knowledge representation.

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