Academics' views of adaptive e-learning technology in a South African university

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Abstract: The current study draws on research conducted on cognitive enhancement and adaptive e-learning technologies at a South African higher education institution. The research was motivated by the failure of implementation processes or delayed adoption rates regarding Adaptive E-Learning (AEL) technologies as compared to other industries or environments. This study was conducted involving ten academics recruited from a South African university. The design was exploratory in which participants' experiences were analysed via discourse analysis. This study found that too many of the university faculty participants lacked sufficient understanding of AEL for AEL to be adequately implemented and used at the university.

Keywords: adaptive learning technology; e-learning; e-health; computational cognition; information processing.

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1 Introduction and problem statement

In most countries, cognitive enhancement has been characterised as improving or augmenting information processing (computational cognition) via adaptive electronic learning (e-learning) systems/technologies (The Royal Society, 2011). Cognitive enhancement and computational cognition are used interchangeably in the current study. Herein, cognitive enhancement refers to enhancing mental / intellectual prowess leading to increased problem-solving ability or memory (The Royal Society, 2011, p.5). Bostrom and Sandberg (2009) examined methods, ethics, and regulatory challenges associated with cognitive enhancements. More recently, Musheer (2018) examined Information and Communication Technologies (ICT) as a catalyst for the teaching-learning process. In South Africa, Adaptive E-Learning (AEL) systems (see background for definition), a variant of e-learning, has been receiving noticeable attention, primarily in how to enhance learning and cognition (Bharuthram and Kies, 2012; Murphy et al., 2001; Njenga and Fourie, 2010; Palloff and Pratt, 2010; Pollock and Cornford, 2000).

While there are several benefits and challenges, an AEL system could be described as "an interactive system that personalises and adapts e-learning content, pedagogical models, and interactions between participants in the environment to meet the individual needs and preferences of users if and when they arise" (Stoyanov and Kirchner, 2004, p.41). Albeit with remarkably varying outcomes, recent attention has focused on enhancing cognition through e-learning (Adams-Becker et al., 2017; Bates, 2015; eLearn Center, 2017; Ferguson et al., 2017). For instance, the eLearn Center (2018) reported on the 20 most frequent e-learning indexed research topics. Among others, these included adaptive learning, literacy, blended learning, mobile learning, e-learning adoption, intelligent systems, game and gamification, and virtual reality. This report also noted research methodologies associated with these e-learning studies including descriptions (38.8%), evaluations (18.0%), experiments (15.9%), designs (9.8%), reviews (9.4%), case studies (8.0%) and others (<1%), with the majority of research concentrated on undergraduate teaching and learning (56.6%). Practitioners are aware of common e-learning tools used in higher education such as: web log (blog); social bookmarking, used for web-based service to share internet bookmarks; Really Simple Syndication (RSS), used to publish frequently updated digital content; and instant messaging such as Gtalk, Skype, Meetro, ICQ, and podcasting.

Despite the variation in methodologies and findings, researchers have advocated for AEL as a vital means of cognitive enhancement. Although far more broadly advocated for as a significant means to enhance cognition, research has linked sophisticated AEL technology with cognitive-enhancing therapeutic pharmaceuticals (The Royal Society, 2011). In comparing AEL and pharmaceuticals as means of cognitive enhancement, AEL outweighs most enhancers and is regularly recognised as one of the most successful cognitive enhancers of all (The Royal Society, 2011). This may be so because AEL systems serve as a means of access to strategies for abstract thought processes, such as are needed in problem solving in cryptography, logic and algebra in computer science/mathematics. In the context of gaming, adaptive game-like programs operate on an individual's natural reward system, wherein this form of learning assists in knowing which action has the most valuable outcome (The Royal Society, 2011). Through understanding of cognitive informatics and gamification, abstract thought processes may be decontextualised and explained in a range of challenges, which may increase abilities in mental or cognitive flexibility (The Royal Society, 2011). Thus, insights from cognitive informatics regarding technology, and subsequently cognition, are important. Indeed, it is believed that technologies and computer games could be designed to support and enhance cognition, even regarding higher level cognitive domains such as application, synthesis of ideas, evaluation, and creation of ideas.

However, due to several factors, such as failure of implementation of AEL technologies, particularly in South Africa, the few specialised teachers of AEL systems have limited knowledge of AEL technologies and hence, struggle to learn more of, implement, advance, and disseminate information about, AEL technology (Bharuthram and Kies, 2012). Nevertheless, The Royal Society (2011) insists on the importance of advancing AEL technologies by adding that an AEL system has the potential to complement the teacher by targeting learning experiences.

Altogether, there is a need for continued research into AEL technology. This is necessary in the domain of higher education, where instruction and learning is often contextualised in technology environments. This current research is guided by examining AEL systems and cognitive computing (information processing) in higher education through the works, among others, of the eLearn Center (2017, 2018), Ferguson et al. (2017), Bates (2015), Adams-Becker et al. (2017), The Royal Society (2011), and Bostrom and Sandberg (2009). As a consequence of the introductory section, the following forms the basis of the study's objective:

1.1 Objective of the study

The primary thrust of this study is to investigate the beliefs and attitudes of university faculty who purport to use AEL in instruction and student learning, and compare these opinions with existing research on cognitive enhancement and AEL systems in higher education.

2 Review work – criticisms of an adaptive e-learning system and its use cases

Regardless of the benefits of AEL, various challenges have been recognised as hindering its implementation. Skills in language, literacy, and numeracy tend to have an impact on the effective use of AEL (The Royal Society, 2011). Determinists suggest that the path of neurological patterns sets individuals on an unchangeable trajectory. Smith and Hardman (2014) explored the influence of learning-assisted programs and computer software, and questioned whether training necessarily transfers to good performance. In some dimensions, their research contrasted assumptions underlying the need for the implementation of computer-based technology and mathematics software. Indeed, their findings in respect to South Africa challenged the notion that computers assist in learning and make significant contributions to education.

Conversely, there exists substantial evidence suggesting positive results from employing AEL toward increasing working memory and learning (Barrow et al., 2007; Christmann et al., 1997; Forsythe, 2007; Harrison et al., 2004; The Royal Society, 2011). In support of these studies, The Royal Society (2011, p.14) argued that AEL systems could be "…developed to support individualised self-paced learning and highly specialised practice in a game-like way." To this end, "…interactive games of this kind use a [student-lecturer] model to adapt the task to the students' needs, and a task model to provide meaningful feedback on their actions" (The Royal Society, 2017, p.14). With ongoing research and understanding in higher education, a further development of cognitive enhancement using AEL technology may contribute to overcoming current challenges to its implementation (Bostrom and Sandberg, 2009).

Potential implication 1

A possible implication is that AEL could enhance personalised and interactive experiences in more real and simulated environments better than other cognitive-enhancing experiences. However, higher education has been beleaguered with (in)appropriate methods of implementing and using AEL, and lags behind other industries such as e-health (medicine), aviation, and e-banking, where adaptive technologies have been successfully applied and advanced. Some of the following background is devoted to exploring AEL in parallel industries from which higher education could learn some lessons.

2.1 Adaptive e-learning systems in higher education; methods, contracts and challenges

Contrasting, but significant strides

AEL research in aviation, e-banking, and e-health demonstrates novel approaches and methods with profound results. Some of these include; in the realm of business (e.g., the Internet of Things (IoT) and business analytics and sensor networks); in the medical field (e.g., applications in healthcare systems, smart systems for behavioural change, implanted sensor-based visual prostheses and body sensor networks, IoT in medical emergencies responses, drug trial and patient monitoring devices, pacemaker and cardiac performance monitoring devices, and medical response services and devices); and regarding home concerns (e.g., smart home systems and disaster management services). Conversely, educators are usually limited to both the open source learning management system (e.g., Moodle and Blackboard) and software (e.g., MATLAB, Geometer's Sketchpad, R, and GeoGebra) mandated by their respective universities. Unlike in the medical field, wherein individualised, smart, adaptive, and internal-wearable medical devices are commonly used, in higher education, no such individualised applications are even at advanced stages of testing (beta versions) (Bostrom and Sandberg, 2009).

Potential implication 2

With the wide-ranging and invaluable applications of adaptive technology in other fields, one wonders why higher education appears to be hesitant in considering and implementing AEL in learning and cognitive enhancement. A myriad of reasons has been suggested, promoting the need for research regarding factors that enhance computational cognition and information processing via AEL (Bostrom and Sandberg, 2009). Particular cognitive factors that are necessary for acquisition of advanced skills in computation have been noted (Bostrom and Sandberg, 2009; (e.g., Deary et al., 2007; Spinath et al., 2006) including working memory (e.g., Passolunghi et al., 2007; Swanson and Kim, 2007), spatial processing (e.g., Guay and McDaniel, 1977; Jones and Burnett, 2008), and language abilities (e.g., Koponen et al., 2007; Lee et al., 2004). Connecting some of these dimensions, Koponen et al. (2007) established a moderate relationship between phonological awareness and text reading ability and computation fluency for fifth graders ($r = .49$). This was accounted for its spatial ability as well as processing speed in terms of computational cognition. Consequently, AEL systems have been receiving growing acknowledgement, fundamentally due to advances in the information process (cognitive process) and from diverse fields or industries as aforementioned (Dominic and Francis, 2015; Räsänen et al., 2009; Wu et al., 2018; Zhang, 2004).

Potential implication 3

Effectively, it is suggested that e-learning is capable of incorporating AEL applications in student cognition (learning) as well as teaching. This capability is commensurate with Rosenberg's (2001, p.28) definition of e-learning as "…the use of internet technologies to deliver a variety of solutions that enhance knowledge and performance" and takes into account learners' different prior knowledge, experience, cognitive abilities, and goals. As a result, "…adaptive e-learning systems refer to a set of information techniques oriented to offer all students appropriate learning materials in response to their requirements and characteristics (Wu et al., 2018, p.903). Accordingly, Räsänen et al. (2009, p.452) stated that cognitive enhancement via adaptive learning technology

> "…could be considered as real teaching machines specially for enhancing cognition" [for which] "typically, three requirements have been regarded as important: (1) The machine must present information in the form of a task, (2) it must provide some means to respond [to it], and (3) it must provide feedback about the correctness of the response… [T]he new possibilities of automated computing enable us to include two other requirements: (4) The system should be able to adapt the task conditions online to maximise learning, and (5) when an error occurs, the system should give feedback that minimises the probability of failure next time."

The question thus arises from this characterisation as to whether it is possible to design a miniaturised version of AEL for the university educational system as a cognitive enhancer. Conversely, it is still a matter of debate as to how many current computerised teaching systems meet these characteristics. These debates are important to be resolved in order to improve students' attitudes and conceptual and procedural understanding in computational cognition (Butterworth et al., 2011; Mendezabal and Tindowen, 2018; Safdar et al., 2011; Smith and Hardman, 2014).

Potential Implication 4

There continues to be a need for an AEL system designed for augmenting knowledge production in higher education (Akbulut and Cardak, 2012; Butterworth et al., 2011; Mendezabal and Tindowen, 2018; Safdar et al., 2011; Smith and Hardman, 2014). For two decades, concepts such as AEL systems, adaptive educational hypermedia, and the adaptive web have prominently featured in research (e.g., Akbulut and Cardak, 2012; Brusilovsky and Maybury, 2002; Ford and Chen, 2000; Froschl, 2005; Graf et al., 2009; Hung et al., 2009; Wu et al., 2018). Many studies have recounted the effectiveness of AEL on students' academic learning, motivation, and lifelong learning (e.g., Mumtaz, 2000; Musheer, 2018; Safdar et al., 2011; The Royal Society, 2011). Others have investigated the use of AEL and ICT in the context of abstract topics such as computer science and mathematics, in which students perennially struggle with both understanding and communicating about the disciplines (e.g., Kallai and Tzelgov, 2009; Meert et al., 2009; Muzheve and Capraro, 2012; Opfer and DeVries, 2008; Schneider and Siegler, 2010). Some have recognised that when students struggle with mathematical content within computer learning environments, misunderstandings are mostly tracked to issues concerning student cognition rather than computer science or mathematics themselves (Lyons et al., 2014).

Despite the increasing need for AEL research, Mumtaz (2000) suggested several factors for slow uptake of AEL implementation; factors that are largely attributed to the marginal quality of some software options, national policies regarding AEL systems, and the lack of pedagogical integration. Mumtaz (2000, p.319) also opined that "…successful implementation of ICT needs to address … interlocking frameworks for change…". These interlocking frameworks include the nexus of the students, teachers, institution, and policy-makers. Another challenge to the implementation of AEL in education has developed from the definitional imprecision with which some terms regarding ICT and AEL are discussed. Consequently, there exists a myriad of definitions, applications, and even misapplications of technology. For example, inferred from Guilhermina's (2007) opinion, applied educational technologies are mostly synonymous with educational technologies since the former involve every aspect of technological applications, their processes, and educational functions, which may include but are not limited to course management. Similarly, for Thompson et al. (1996, p.2), educational technology and instructional technology are interchangeable, since both are used for "theory and practice of the planning, development, use, management and evaluation of learning processes and resources." For that reason, Guilhermina (2007) suggested that technological education could consequently; imply the ability to know the functionality of technology together with the assessment of its effect and how it evolves with society. In contrast, "ICT combines computer technology and telecommunication technology, especially in the world wide web, while computer literacy is considered to be a collection of competences as well as knowledge combined with attitudes" (Guilhermina, 2007, p.41).

Considering the seemingly endless discourse on AEL systems in higher education with mixed foci in terms of methods, challenges, and contracts, the current study examined university opinions regarding cognitive enhancement via AEL technology. This was conducted through seeking experiences / views of ten academics recruited from a South African university. The design was exploratory in which participants' experiences were analysed through discourse analysis as further explained in the following section.

Summary

As seen above, there are many implications to the background material. The participant interviews in this study seek to shed light on some of these implications.

3 Methodology

In examining cognitive enhancement through adaptive learning technology, ten (10) academics (denoted, R1, R2, R3, ..., R10) were recruited from a South African university. The participating academics were in the university's department of mathematics, sciences, and technology education. All participants had access to, and expertise with, how the university's e-learning portals work, how many academics utilise them, and how they are purported to enhance learning. The university used the open source learning management systems Moodle and Blackboard and the department made use of software platforms such as MATLAB, Geometer's Sketchpad, R, and GeoGebra.

A questionnaire was designed for determining their views regarding the use, importance, and implementation of AEL systems in university students' learning. The task was adapted from the problem statement, the literature, contestations and gaps found in the literature, particularly regarding cognitive processing via AEL systems (e.g., Deary et al., 2007; Spinath et al., 2006), working memory (e.g., Passolunghi et al., 2007; Swanson and Kim, 2007), spatial processing (e.g., Guay and McDaniel, 1977; Jones and

Burnett, 2008), and language abilities (e.g., Koponen et al., 2007; Lee et al., 2004). Participants were allowed to either write their responses to the questionnaire or provide oral answers that were recorded and transcribed.

The project was implemented in the first semester of the 2019 academic year and examined participants' understanding of AEL technology by investigating definitions, methodologies, and factors promoting AEL. Noesgaard and Ørngreen (2015) recount that many studies have used various quantitative and statistical methodologies to examine learning through AEL technology (e.g., Grgurovic et al., 2013; Means et al., 2013; Rosenberg et al., 2003; Veneri, 2011). However, this current study employs a qualitative, Exploratory Data Analysis (EDA), methodology (Given, 2008) to investigate participants' opinions. In this study, data analysis was performed through discourse analysis (Gee, 2005; Johnstone, 2002; Schiffrin et al., 2001). Participants were interviewed regarding their level of understanding of: information systems, computer applications technology, information processing and computational cognition, and learning through AEL technology. Through discourse analysis, the researcher sought to discover and review patterns, themes, and discrepancies among responses. Ethical consideration in terms of anonymity and privacy were observed at all times.

4 Results and discussion

Definitions

One of the difficulties immediately recognised in analysing participants' responses parallels the findings previously mentioned (e.g., Guilhermina, 2007; Thompson et al., 1996) that inconsistencies arise among definitions of ICT and AEL nomenclature and applications. For instance, when participants were asked to define AEL technology, R1 used the description: *technology that adapts to one's unique way of learning over time. The technology collects data about how one learns to improve one's future learning experiences.* (This has some consistencies with responses from R4 and R9.) However, R3 added that computational cognition should be referred to as: *the brain's ability to compute. It could be a human brain or a computer's operating system. But I think in higher education it means both. It could mean to study cognition, or to use operating systems.* (R8 had similar opinions.) Notably, the articulations from R1 seem more refined and precise than those by R3, who, in further communications, stated that *all the technology we use can provide students with different assignments based on needs. This is AEL*. (Similar responses were provided by R2, R5, and R8.)

At variance with R3, R5 suggested that cognitive enhancement via AEL technology in higher education (and everywhere) … *could mean to use technology to enhance computational cognition, information processing, and use computer applications… for learning and to study learning*. (These ideas are consistent with R4 and R7.) Defining information processing, R5 articulated, …*a process of decrypting pieces of information, which appear disconnected to make connections, so to understand a phenomenon or solve a problem. This could be done in higher education to understand student experiences, failures, and success within the higher education system*. (Similar notions were stated by R1, R2, R4, and R9.)

While these few responses clearly indicate that the participants had differing understanding of AEL, many held the belief that any technology through which instructors could provide, or students access, different assignments could be considered AEL (R2, R3, R5, R7, R8). This is notably far from characteristics of AEL provided by Wu et al. (2018) and Räsänen et al. (2009), and may in part explain the respective department's limited implementation of AEL.

Consistent with the response of R1, R9 suggested that cognitive enhancement via AEL technology should be seen as *software that elicits particular responses from the students. The software then manages the interaction, leading to a 'custom-based' learning environment for the learner in question*. (This is similar to R4.) However, for AEL technology, R9 argued that it should encompass *…software development that mediates the learning process by customising the learning environment* (R1, R4). In this case, R9 was consistent with the opinions of Bostrom and Sandberg (2009). Conversely, R10, when asked for a definition for AEL, stated, *I don't know. I teach with technology, but I don't think that I have an exact definition for AEL* (Similar to R8).

While all research participants in this study worked in the same department in the same university and had access to the same technological resources, participants had differing levels of knowledge of AEL. Notably, the literature seems to tie information processing with computational cognition through the mechanisms of obtaining, retaining, and reproducing information contextualised within a task (Ansari, 2008; Bostrom and Sandberg, 2009). In AEL architecture and information processing, these three mechanisms have evolved unevenly over time without established results, particularly in most African institutions of higher education. This may explain the difficulty in succinct explanation of some of the concepts of AEL as noted by some of the participants.

In summary, it can only be assumed that inconsistencies among participants' notions of the nature of AEL would certainly affect the implementation of AEL within a particular department. This is all the more so when all participants work in the same department in the same university. It must be wondered how more consistent definitions could be shared within a department and across a university.

Applying AEL

In studying cognitive correlates of performance in computational cognition, Wei et al. (2012) suggest that not much advanced research is devoted to advanced computational cognition such as artificial intelligence, cryptography, or modern algebra logic. This is seen in the statements of R1: *I have not seen true AEL in higher math university courses. It seems like all those options are for lower level courses with a greater number of students in each class. And, I have not seen much research regarding student learning in these environments. It seems like they are most geared to classroom management of larger classes than really investigating if students learn better.* (R4 and R9 had similar comments.) Since some of the participants in this study had expertise in some of these fields and not in others, this may also partially explain why some participants, such as R1, R7, and R6, do not share the same views.

A suggestion provided by Wei et al. (2012) is more consistent with the view of participant R9, who argued that computer applications should *deal with the technology that is involved in the use of computers in solving problems (all kinds of problems!!).* Participant R9's view should not be limited to only elementary studies. While R9's view is consistent with the work of Wei et al. (2012), it is evident that not all academics are fully abreast with the notion of computer application technologies. As stated by R5, *I use* *technology in my classrooms. The students use MATLAB and Blackboard to solve problems. Even if they all get the same problems, they solve the problems in their own ways. They adapt MATLAB to solve the problem* (Similar to R3, R6, R8). While R5 has a distorted view of AEL, it may still be more valuable than the view of R10, who, when asked what computer application technology referred to, simply declared, *I don't know* (Similar to R8).

Motivating the needs for research regarding computer application technologies, Wei et al. (2012) argued for the importance of promoting advanced computational cognition among university students and investigating all factors (including cognitive factors) that are important for acquiring advanced computational cognition. While understanding information processing of elementary computation tends to enhance our understanding of computational cognition, such research tends to be limited, especially at advanced levels of cognition and mathematical topics. This cumulative effect of early foundational skills on later outcomes has been referred to as the 'Matthew Effect' (Ansari, 2008), implying that the importance of studying foundational systems in an effort to improve the starting points of skill acquisition, may have a dramatic, cumulative influence on later outcomes. Thus, based on the assertion of Wei et al. (2012) and due in part to the three earlier mentioned mechanisms, much of the focus of the current research was inspired by the tremendous progress that has been made on the development of reading skills amongst children and AEL architecture (Lyons et al., 2008).

In contrast to participants such as R2, R9 and R5 (R5 stated, *while I believe in the power of technology, I confess that I rarely see provable results regarding improving student learning*), and despite the consequence of Matthew Effect, Wei et al. (2012) reveal that basic numerical processing and computation do not generally correlate with performance in advanced cognitive computing. For instance, after controlling for other factors, Wei et al. (2012) establish that spatial abilities significantly correlate with mathematical performance in respect to advanced computational cognition. Additionally, Wei et al (2012) find that rather than basic numerical processing, spatial abilities, together with language comprehension, plays a crucial role in advanced computational cognition. Consequently, enhancing cognition through AEL technology has become imperative since, in a parallel manner, teaching and learning processes have become more interactive, engaging, and collaborative through technology-based instruction (Mendezabal and Tindowen, 2018; Grabner et al., 2007). This view is consistent with the participants R1, R2, R3, R4, R5, and R9.

Even though some participants such as R3, R5, R6, R8, and R10 revealed limited knowledge of AEL integration in the classroom, it is believed that all could both continue to create innovative and student-centred learning materials and aid in the process of AEL technology implementation at the university (Mendezabal and Tindowen, 2018). As previously mentioned, there has been a substantial body of work demonstrating an inclination to use AEL in teaching and learning, with frequently mixed results (Agyei and Voogt, 2011; Barrow et al., 2007; Bostrom and Sandberg, 2009; Dehaene, 2009; Grabner et al., 2007; Harrison et al., 2004; Lyons et al., 2014; Mendezabal and Tindowen, 2018; Räsänen et al., 2009; The Royal Society, 2011; Zago et al., 2001). For instance, it has been confirmed that "…the use of the applets created with the help of GeoGebra and used in differential calculus teaching had a positive effect on the understanding and knowledge of the students" (Mendezabal and Tindowen, 2018, p.385). The suggestion is that there exist connections among conceptual understanding, procedural skills, and comprehension. Parallel research demonstrates that the implementation process appears slow (Safdar et al., 2011). Even though participant R3 echoed the need for *technology that provides assistance supporting and facilitation of the functioning of the mind*, challenge of implementation remains at the core of AEL.

R1 stated that, *I don't think that I have actually seen any AEL applications using Blackboard or Moodle or using any of the software packages we use. Although I may use these products to create activities that differentiate among weak, medium, and strong learners, this is far from a system that automatically adapts to the learner. So, I don't know anyone in the department who actually employs AEL technology in their instruction. R9 paralleled this sentiment by stating, how can we possibly apply AEL? We really aren't using any AEL-based technology. I've seen it in entry level courses, but not in upper level courses. MATLAB really isn't an AEL technology. It doesn't adapt to the learner*. (Similar statements were provided by R1 and R4.) Altogether, R1 and R9 demonstrated a strong understanding of AEL and its implementation, together with an understanding of what AEL is not. Indeed, this full understanding of AEL seems absent in the remarks of almost all other participants, who seemed more interested in seemingly defensively justifying their use of technology as AEL. R1 further responded, *I don't think that we can keep up with other industries using adaptive technology. They are profit-based in ensuring that the adaptive technology drives people in making money for the industry. Higher education is under no such illusion. In fact, I would argue that, as much as possible, although we give lip service to differentiating instruction to meet the learning of individuals; we are truly more looking for a one size fits all manner of teaching. So, some universities try to use AEL in lower level, high population, Math classes as a panacea for all*.

In summary, participants who seemingly knew less of AEL and its appropriate applications seemed more defensive in their responses and more strongly insisted that their instructional uses of technology were appropriate implementation of AEL. Participants who seemed to have well-formed ideas of what AEL is and how it is or should be applied, seemed more certain that they were not appropriately using AEL in their teaching profession.

5 Concluding remarks and hypothetical stance

Considering both the participants' views and literature from previous works, the results remain mixed. While overwhelming participant responses suggest that the faculty advocated for the use of AEL technology, they had significantly different views regarding such use. Indeed, faculty had inconsistent views regarding whether they were each properly applying AEL in their regular practices.

The recommendation from this study is that there remains continued need for advanced training of university faculty in the constructs and applications of AEL technologies in order to empower change at the university level. We argue that until faculty are sufficiently knowledgeable in AEL matters, there is little hope that students will benefit from AEL technologies. Researching the actual effect of AEL technology in learning may be premature.

It is important to realise that this research occurred at one university with faculty from one department. While it may be inferred that these faculty were unusually weak regarding AEL technology, the researcher assumes that this is far from the case. Indeed, we hypothesise that if faculty were generally investigated from almost any university, similar results would ensue. Thus, there is extensive need to concretise notions regarding AEL within any university and possibly beyond in order for successful implementation to occur.

6 Future research

This current study is planned as the first of a two-phase research project. Phase 2, to be completed in the near future, will take the form of either Electroencephalogram (EEG) or Functional Near-Infrared Spectroscopy (fNIRS) to examine from a neurological perspective how an AEL system can enhance computational cognition. These two phases of study will form a triangulation, including qualitative and quantitative approaches and provide an opportunity to further examine underlying evidence related to the influencers (computational processing) used in (1) obtaining and processing, (2) retaining, and (3) reproducing information contained in a task.

Unfortunately, the drawback to research such as proposed in Phase 2 has been a lack of adequate AEL understanding and implementation. Bostrom and Sandberg (2009) lamented that regardless of the need to carry out such investigations, the lack of adequate techniques and on-going fragmented debate has also fuelled a suggestion that computational cognition, which may include but not be restricted to numerical and visual processing / analysis, largely occur with limited neuronal comprehension. To investigate such dimensions requires integrating research in both neuro-imaging and adaptive e-learning system research through the lens of information processing for cognitive improvement.

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