THE MYSTERIOUS MANTLE OF TECHNOLOGY: ELABORATIVE ANALOGY AND DISTANCE EDUCATION

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ABSTRACT
With continuing expansion of online learning and an increase in the use of computer technology, the complexity of technology can complicate the understanding of computer concepts. Elaborative analogy may help to enhance understanding and speed the learning process. With the ever increasing growth of computer use and technology in online education, the purpose of this study was to empirically evaluate a model of teaching and online learning designed to help students better understanding of basics of technology. A model of elaborative analogy was developed by the authors modeled after the Human Information Process (HIP) with the intention of enhancing the understanding of ubiquitous computer technology used throughout online education. A cognitive map may be drawn to assist students in the assimilation of new knowledge regarding basic computer understanding and function in relation to the HIP. Perceptions and attitudes toward the efficacy of the model were examined in this study. Results of a survey designed to measure student (n = 64) perceptions about an expanded Input-Process-Output (EIPO) model of computer technology were found to be favorable overall and support the need for further research.
Keywords: Elaborative Analogy, Human Information Processing, Teaching, Learning, Cognition, Constructivism, Technology, AI, Distance Education

Introduction

Technology has had and will continue to have a significant influence on all aspects of society (Blut & Wang, 2020; Tipton, 1998). Computers have become an integral component of daily life. As Morrette (1988) predicted years earlier, the invention and development of the computer will continue to have an impact on all human experience. Work, manufacturing, and growing segments of education, including an exponential rise in online learning and distance education are increasing in their dependence upon computers, education, and learning. The phenomenon can be thought of as a paradigm shift, a change in the way society perceives, learns, and interacts, a phenomenon that is changing at an exponential rate, and one that may be described as 'staggering' (Dennis, 2017; Harrington, 2011).

Computer literacy is fast becoming an expectation of academicians, students, and administrators (Blut & Wang, 2020). Theoretical and application concepts are more or less taken for granted in most educational settings. Yet, unlike subjects like arithmetic or language, for example, computers and technology may be foreign to students thrust into distance education settings. The technological perplexity of understanding and operating a computer, smartphone, or tablet, for example, combined with uncertainty due to lack of previous knowledge, can result in an enigmatic and exasperating experience for distance education learners. Even those who grew up with computer games, cell phones, and laptop computers may not fully comprehend technological fundamentals, leading to what may be a mysterious experience or perhaps a state of technology anxiety (Blut & Wang, 2020) - technophobia.

Effective teaching doesn't just happen. It involves more than just knowing the subject matter (Davis, 2019). Effective teaching can be defined as "…the art of getting information to the students' memory in an organized manner to facilitate later retrieval." (Hutchison & Padgett, 2007, p. 69). The use of elaborate analogy may help relate new information to what students already know. The importance of constructing meaning by relating previous knowledge to new information is well-documented (Holyoak & Thagard, 1997; Oppenheimer, 1956; Ormrod, 2020; Ormrod, Ormrod, Wagner & McCallin, 1988; Piaget, 1977; Royce & German, 2019). According to Armelin, Heinemann, & de Hoz, (2017), learning can be facilitated when information is incorporated into an existing, learned set of rules, or "mental schema." The task of presenting difficult new information can be mitigated to one extent or another by overlapping that information with previous knowledge, with what is already known (Gentner & Holyoak, 1997; Lu, Wu, & Holyoak, 2019; Ormrod, 2020; Paris & Glynn, 2004, Vamvakoussi, 2017). People inherently know something about themselves from a physiological perspective, presenting an opportunity for relational analogical learning. In early years of development and with little guidance, toddlers become self-aware. Teaching children to identify body "hardware" (e.g., eyes, ears, hands, etc.) often occurs as early as the sensorimotor stage (birth to 2 years of age), Piaget's earliest stage of development (Flavell, 2000; Piaget, 2000).

Technological Imperative

Previous knowledge of aspects of technology may be virtually nonexistent for those inundated with or compelled to use technology in their daily work. In this case, in online or distance learning, presumption of computer skills is often taken for granted. Knowledge may be incomplete, or at best, imprecise in those learning to use the technology for the first time. A significant population represented by this phenomenon may include preadolescent and adolescent students in K-12 settings or adult learners pursuing an online degree at the undergraduate or graduate level. Previous knowledge of computer technology may even be limited in those who are comfortable with the use of smartphones, tablets or laptops. People educated in previous generations received little or no computer training in public or private schools, nor had ready access to technological devices such as computers, iPads, or smartphones. Many still don't today. Even children who appear to be computer literate may know how to *play* computer games without truly understanding fundamental computer concepts. As Morrette (1988) envisioned years earlier, many young people were reared in home and school environments where computer knowledge was not valued or not available due to societal inequities. The same may hold true today. Even where lack of previous knowledge exists, there may be metacognitive methods of teaching and learning about computers that can enhance the learning process, improve learning, and assist in the retention of important, useful computer and technological concepts, assisting those who are now faced with aspects of technology, educating online. Through the challenges, lack of previous knowledge, and ever increasing presence of technology, a technological imperative persists, demanding at the very least a basic understanding of hardware devices and software applications.

Metacognition & Constructivism

Metacognition is widely considered salient to efficient learning and is defined as the act of thinking about one's own thinking (Ganz & Ganz, 1990; Heyes, et al., 2020; Ormrod, 2020). The greater a learner's metacognitive self-awareness, the more likely that learner is to achieve (Hofer & Pintrich, 2002). Drawing meaningful comparisons to that which learners inherently know about themselves has shown promise as a method of improving learning and retention. Students appear to achieve relational understanding when they are actively engaged in constructing their own knowledge (Glaser, 1991; Hwang & Chang, 2021). Self-reference appears to be a powerful encoding system, functioning as a superordinate schema (Markus, 1977; Rogers, Kuiper, & Kirker, 1999), a Piagetian cognitive construct to which new information can be learned through assimilation or accommodation (Armelin, Heinemann, & de Hoz, 2017; Piaget, 2000). Clearly, schemas contribute to learning and retrieval of information (Sakamoto & Love, 2004). According to Ormrod (2020), the task of relating new information to one's self can have a dramatic effect on learning. Evidence points to the fact that the more learners relate new material not only to existing material but also to themselves, the more meaningful learning is likely to be (Glaser, 1991; Rogers, Kuiper, & Kirker, 1999). In particular, elaborative analogy appears to be more effective than simple analogy alone in the acquisition and retention of knowledge (Paris & Glynn, 2004) and can serve as an inspiration to learning (Glynn, 2008). Elaborative analogy incorporates visual images and text, promoting organization of information into a more meaningful concept map, helping the learner to map concepts from the analogy to the target (that which is intended to be learned).

Pedagogy

The pedagogical process appears to be improved by organizing information for learners. Comparative organizers (i.e., comparing computers to people) help to establish meaningful learning sets. People then begin to understand new material at a more meaningful level (Ausubel, Novak, & Hanesian, 1978). Research suggests that overlapping new information with what people already know can increase comprehension (Ormrod, 2020). Adding comparative organizers, memory maps, and analogous materials to the pedagogical process may improve teaching and learning in technological areas. To support this further, reading may not be the most efficient method of learning. For example, Paris & Glynn (2004) evaluated the use of elaborate and simple analogy in the teaching of science to a diverse group of students at a large university (N = 140). Their empirical findings suggested that elaborate analogies tended to improve the learning and recall of science knowledge. They noted findings to be consistent with the benefits of a constructivist view of learning. Ngu & Phan (2020) proposed a model designed to aid students in learning trigonometry. Their model drew upon the complementary strengths of learning through the use of analogy and learning by comparison. The goal was to help counter the inherent difficulty of learning subjects like trigonometry. Their conceptual compared pedagogical approaches for effective teaching and learning of trigonometry. A similar condition may exist when expecting students to comprehend knowledge about computers and technology, inherent in the employment of distance learning platforms, for example.

In an earlier study, Yanowitz (2001) examined the effects of analogy in a K-6th grade environment. Scientific concepts were taught to some students using instructional analogies and to others in expository text absent of analogy. In two separate experiments, students who were presented material using analogical text showed higher levels of performance on inference questions than those who received the non-analogical texts and appeared to demonstrate better inferential reasoning than students who were not exposed to analogical texts.

The IPO Model

The predominant paradigm for teaching basic concepts of computers is the ubiquitous Input-Process-Output (IPO) model of computing as shown in Figure 1. This universal concept has appeared regularly over the years throughout computer textbooks in one form or another (Hennessey & Patterson, 1998; Parsons & Oja, 2013; Peat, 1988; Shelly, Freund, & Vermaat, 2011; Szymanski, Pulschen, & Szymanski, 1995). Input to the computer takes place through input channels. Information is then sent to the processor, where any number of operations may take place. In a computer, data is processed through memory, the arithmetic unit, or the control unit. Output from the processor is received by an output device such as a computer screen, file, cloud server, printer, external storage device, or a speaker.

Fundamentally similar, nearly all computers in operation follow the Von Neuman processor concept, illustrated via the IPO model seen in Figure 1. Even high-powered supercomputer vector processors and "fuzzy logic" computers follow the IPO model, just as smartphones, pads, and laptop computers do to this day. This model serves as an essential foundation in introductory computer classes and in courses in which computer concepts are taught as an adjunct to the primary curriculum. The same model appears to parallel human information processing.

Human Information Processing

Human Information Processing (HIP) is an area that may be drawn upon to enhance learning about computers. The HIP model may help the student organize information, mapping that information to her or his psychophysiological self, and compare that new information to existing knowledge, as shown in Figure 2. HIP employs terms such as the cognitive process, learning vs. memory, storage, retrieval, and encoding (Ormrod, 2020). Computer processing employs similar terms such as memory, storage, retrieval, coding, programming, and processing.

The mind and the computer have much in common (Cuzzolin, et al., 2020; Peat, 1988) and is demonstrated by the surge in neural networks and artificial intelligence, a branch of science that incorporates neuropsychological concepts with those of computers (Minsky, 2019). In artificial intelligence (AI) systems, computers learn. In human education, people learn. Throughout the cognitive study of human memory, concepts of sensory register, short-term memory, working memory, long term memory, capacity, and forms of storage are discussed. Computer vernacular includes concepts such as short-term memory, often referred to as working memory or random access memory (RAM). Concepts of long term storage and storage capacity are also used throughout computer technology education. Even in information science education, constructs such as propositional networks, models of reasoning, logic dependencies, and association of ideas overlap (d'Avila Garcez & Lamb, 2006; Rödder & Kulmann, 2006). Terms including schema, internal coding, and compilation are common to both cognitive psychology and computer sciences. In computer theory, even today, these may be lofty and nebulous concepts to the new learner. Mapped to the human form, such concepts may become more familiar. As they become more familiar, they become less threatening, which may increase students' levels of self-efficacy and confidence to learn.

The Expanded IPO Model of Computing

An expanded version of the IPO model (EIPO) as shown in Figure 3 may be useful as a base for teaching fundamental concepts of computing, as a bridge between theory and practice, and as an aid in organizing new material more efficiently for students faced with online learning. Like the IPO model, the EIPO model outlines the basic components of most known computer configurations, including hand calculators, personal computers, and supercomputers, which may also serve as a model for the human mind. The expanded IPO model adds the concepts of hardware and software to the conventional IPO model, further organizing fundamentals of computing into an understandable format. Logos and icons are superimposed upon the model, which explain each of the areas of input, process, and output within the areas of software and hardware. Hardware devices are paired with equivalent software functions that further organize and link network relationships within the learner's mind. The list structure more closely parallels the propositional network posited as the preferred paradigm of cognitive memory theory (Heyes et al., 2020).

This expanded IPO model may be referred to throughout a computer technology course with varied reference to the framework. The model enables students to organize information and draw comparisons to activities in which computers are involved: from fundamental theory to application of specific computer software applications, such as spreadsheet and database packages, apps and learning platforms. Even during the theoretical and practical learning of word processing or programming applications, references to the associated components of the EIPO model may enhance learning.

A combination of iconic symbols and logogic elements are used to deliver what could be new and complex material to students. This process simulates the conjoint retention theory that suggests that learners are able to utilize two systems of recall; spatial and verbal. Representations from either system can be combined to assist in learning and recall (Webb, Thornton, Hancock, & McCarthy, 1992). The advantage of dual representation appears to be that information stored in either spatial or verbal form can be accessed from either system (Paivio, 1986). The EIPO model can be presented using icons, labels, memory maps to physical human body locations or be used as an organizer allowing students to map new terms to that which learner are familiar. Combining verbal and pictorial material provides an advanced or more elaborative form of analogy and embedding analogy in context may improve inferential learning. Adding pictorial schematics can potentially increase factual learning as well. As Adding situational information provides a more elegant method of analogous learning. Such information may take the form of relating to the human form. Jonasson (2007) posited meaningful learning as consisting of an integration of co-requisite reasoning skills, analogical reasoning, and causal reasoning.

Combining computer theory with what is inherently known about human physiology and mental structure may improve learning and retention of computer-related theory and use. By drawing inferences from the human information process to the computer processor, as shown in the EIPO model (see Figure 2), students can better organize new information, which may then improve both learning and retention. The EIPO model may assist in that process, helping to organize information for learning and providing a method of adding meaning by relating the substance to a well-known entity, the human information system. The job of the teacher can then enable or encourage interpretation by the student, rather than to simply transmit text (Gademer, 2011). The EIPO model may help to close the gap between learner and subject matter, adding a level of personalization to the learning process (Papert, 1993).

The EIPO model encapsulates concepts of hardware, software, and the associated components of each, drawing an analogy to the human form and thereby making learning about computer technology potentially easier. From the perspective of human information processing, within the category of "Input," human input devices such as eyes and ears can then be associated through analogy to corresponding human software functions such as *seeing* and *hearing* to form a complete functioning system. Within the category of "Output," for example, devices such as human vocal cords combine with mental software called *language* or *speech* to parallel a similar concept in computing. Within the concept of computer information processing, a computer's voice output requires both hardware in the form of the speaker and software in the form of a voice synthesis program in order to function. Making the comparison of human language in relation to vocal cords to the computer's speech synthesis software in relation to the computer speaker may ease the task of learning. The connection between the fleeting memory of logogen-based computer teaching and practical application appears to be improved by providing a model like EIPO. Students appear less confused, more attentive, and demonstrate less difficulty in practical application labs upon comprehending the concepts presented in the EIPO model.

Method

Procedure

A survey design was employed in this seminal study to determine whether the Expanded IPO Model (EIPO) could help learners better comprehend computer processing through elaborative analogy. Students from two courses taught at a mid-sized midwestern university were recruited voluntarily to participate in the study, which including a brief demonstration of the EIPO Model followed by completing a simple survey. Both courses were taught at a large, urban, Midwestern college and students were about mid-way through the semester. All participation was voluntary and IRB rules were adhered to. No incentives were offered, and no external funding was used for this study.

Participants

The diverse convenience sample of participants (n = 64) consisted of 23 males and 41 females ranging in age from 18 to 55. Participation was voluntary. All information was kept confidential, and from the onset, no names were collected with the surveys. A brief presentation incorporating the elaborative IPO, HIP, and EIPO models (e.g., verbal lecture, textual and graphic handouts) was then given to the students in both classes. Learners were informed of the conceptual expanded IPO model and how it could better relate to the human form (HIP model). Students were then asked to point to input channels (i.e., eyes and ears) and discuss human processors (i.e., componential brain functions such as memory, cognition, and speech). Following the 1-hour presentation and subsequent discussion, students were asked to complete a brief survey.

Instrumentation

The survey collected basic demographic information excluding name or identifying data. Following demographics were four statements:

1. I found this teaching concept clear and easy to follow.
2. This teaching concept will help me to remember the information.

3. The model presented was a helpful method of learning about computers.
4. I can see this model being used in textbooks to help others to understand the concept of computers.

A Likert-type scale ranging from 1 (lowest) to 5 (highest) was used to rank the level of agreement with each survey question in an attempt to measure student perceptions of this elaborative analogous learning process.

Results

Responses from both groups were found to be significantly favorable on all four survey items with quasi-interval mean scale scores ranging from 4.23 ($s = .90$) to 4.52 ($s = .85$) out of 5. Results of the survey are shown in Table 1, and overwhelmingly support the use of analogy in teaching and learning about technological concepts from the students' perspective. Thus, participants ($n = 64$) exposed to the EIPO model clearly favored the analogous method contained within this model. Observation of students during the process also revealed a high level of attentiveness to the models, although this aspect was purely observational and not empirically derived.

Discussion

Constructed from within the consciousness of the mind, the microcomputer brings with it inherent pedagogical advantage. The ease of accessibility, cost advantage of personal computers, and expanding use of technology and the Internet support the need for new paradigms in education, such as constructivism, cooperative learning, hands-on, peer, and analogous learning. Novice computer students or those compelled by technological imperative do not often reap the benefit of years of pre-school or K-12 fundamentals in building a knowledge base from early years, as they might with arithmetic, literature, reading, writing, or native language, for example. Thus, assigning meaning through elaborative analogy may ease the initial shock of unexpected constructs that students may be faced with due to the technological imperative thrust upon us. Again, inherent in this extension of the human mind, we have the opportunity to use analogy to assist students to genuinely comprehend and retain knowledge. Many new paradigm techniques (i.e., elaborate analogy, constructivism, peer learning, web-based learning) offer students opportunities for more rapidly assigning meaning to theoretical constructs (Slavin, 1991; Williams, 2002). These techniques may also help increase attentiveness and improve the self-efficacy of the learner, help to debug minor glitches, and lead to increased learning and understanding, potentially resulting in the achievement of higher grades and more effective learning environments.

Limitations

Responses to the survey were overwhelmingly favorable to the use of the self-reference and analogy with the EIPO model. Teaching new information in and of itself may enhance learning, confounding the results of this preliminary study. Many factors may be covertly at work in any non-experimental study, this one included. Thus, further research is recommended. Replication of this study is warranted. Research using pre- and post-treatment design or experimental causal comparative methods may provide better control in the measure of learning about technology, Internet, and computer concepts by analogy. An experimental design would be helpful to isolate confounding variables and implicate elaborative analogy as the main effect in better teaching and learning in technology.

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Statements & Declarations
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Table 1 *Means and Standard Deviations of Likert-type Quasi-interval Scale Scores*

	Group 1		Group 2		Total	
Survey question	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
1	4.33	.64	4.46	.82	4.44	.85
2	4.58	.76	4.15	.91	4.23	.90
3	4.58	.64	4.33	1.11	4.38	1.04
4	4.58	.95	4.50	.89	4.52	.85

Figure Captions
Figure 1. The Von Neumann Input-Process-Output model of computing.
Figure 2. The Expanded Input-Process-Output model of computing.
Figure 3. The Expanded Input-Process-Output model of Human Information Processing.

Figure 1.

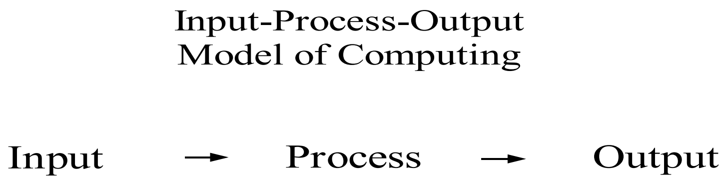

Figure 2.

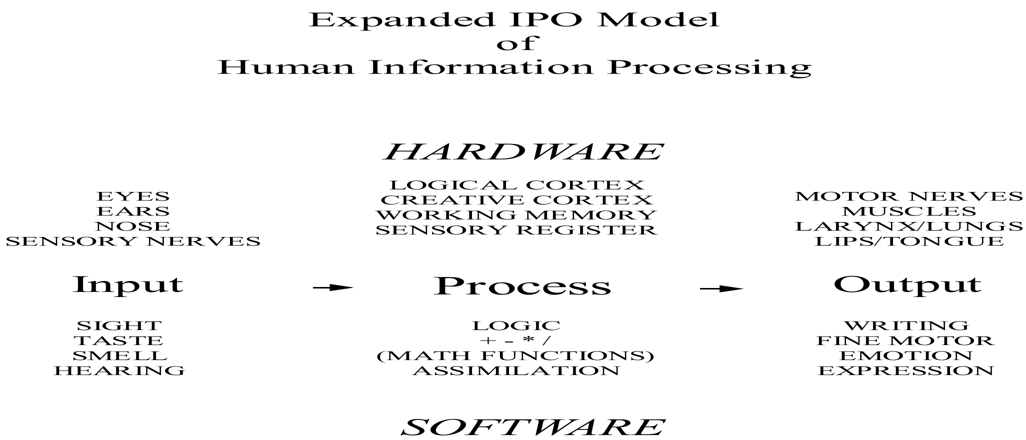

Figure 3.