COGNITIVE SCIENCE IN RELATION TO EDUCATION—A REVIEW

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Abstract: *Cognitive Science is the study of the processes by which the humans and other animals are able to know the properties of their external environment and convert that knowledge into action as well as transmit that knowledge to others through communication. Education is a deliberate process of facilitating development in the individuals. The researcher has observed from various studies that a strong relationship is evident between the fields of cognitive science and education. The objectives of the study are—to review the studies conducted in the field of cognitive science that have implications in the field of education and to find out the trend in researches in cognitive science having implications in the field of education. It is agreed upon that a better understanding about the mind of the learner will lead to effective outcomes of education and cognitive science is the best way to understand the mind. The present study is an attempt to review some researches in cognitive science which shows implications in the field of education. It has been found that most of the studies in cognitive science have established the strong relationship between cognitive science and education. Most of them have advocated for the usefulness of the researches in cognitive science in the field of education.*

Keywords: Cognitive science, Education, Mind

I. Introduction

In the last century, one of the most significant developments in the world of knowledge was in the form of the field of cognitive science. Cognitive Science refers to the field which studies the processes by which the humans and other animals are able to know the properties of their external environment and convert that knowledge into action as well as relay that knowledge to others by means of communication. Broadly, it can be defined as the scientific study of minds and brains—natural or artificial, human or animal. It aims at studying cognition by pooling the resources from a number of disciplines, including psychology (mainly cognitive

psychology), artificial intelligence, linguistics, philosophy, neuroscience and anthropology (mainly cognitive anthropology). As mind is an omnifarious phenomenon, the researches in cognitive science have prospective implications in many important areas like mental health, social engineering, education, computer technology, etc. The present study is an attempt to review some research works in the field of cognitive science which shows its implications in the field of education. The researcher has observed from various studies that a strong relationship is evident between the fields of cognitive science and education.

1.1. Objectives

The objectives of the study are—

1. To review the studies conducted in the field of cognitive science that have implications in the field of education.
2. To find out the trend in researches in cognitive science having implications in the field of education.

1.2. Operational Definitions

Cognitive science—A multidisciplinary field which studies the mind in its natural as well as artificial form.

Education—A discipline which deals with the development of human beings, which includes various aspects like teaching, learning, pedagogy, curriculum, etc.

1.3. Methodology

The present study is conceptual in nature. Various studies in the field of cognitive science have been studied and reviewed and an attempt has been made to recognize the trend of researches in cognitive science having implications in education.

II. Studies in Cognitive Science

Cognitive science researches are concerned with the structure and representation of knowledge in our minds. As a new and emerging discipline, limited studies are found in the field of cognitive science. A strong relationship is evident between cognitive science and education. The applications of cognitive science in the educational process are straightforward. Some

experts are trying to solve the problems of education or to improve educational aspects by using the researches in cognitive science. The main goal of the education process is to improve learning and performance of the students. A thorough understanding of the learning processes is vital for the design and execution of adequate curricula and teaching methods. Moreover, the education process has to consider the information processing in the learner, accessing a learner's cognitive structure (prior knowledge), problems in processing the information and ways of overcoming these problems. A better understanding of the neural underpinnings of learning mechanisms and cognitive functions involved in the educational process (cognitive functions like memory, attention, motivation, perception and metacognition) has obvious implications for making education effective. Cognitive science researches also can also help in designing of effective learning tools and educational paradigms. Teaching is based on the assumptions about the mind of the learner to a great extent. Therefore, it is important for the teacher to determine what children think they are doing and what their reasons are for doing it, apart from knowing what they do. Gardner (1991) has aptly said in his "The Unschooled Mind" as "We must place ourselves inside the heads of our students and try to understand as far as possible the sources and strengths of their conceptions." Cognitive science is the field which can best help at a comprehensive understanding of the human mind.

Glaser (1988) agreed that cognitive science offers a re-conceptualization of the nature of the learning process and new approaches to the investigation of learning. Kruse (1998) reported on the implications of brain research on education, by giving details on how the brain works, the structure of the brain and an in-depth look at human learning in relation to the brain. Kala, & Ramadas (2001) pointed out that developments in cognitive science were found to contribute towards research paradigms and methods, including expert novice studies, problem solving and linguistic analysis apart from the contribution of philosophy of mind. Klahr & Li (2005) stated that cognitive research can generate usable knowledge for elementary science instruction and that issues raised by classroom practice can drive the agenda of laboratory cognitive research.

Leong (1993) argued for the role of an applied cognitive science perspective in education in the paper "Towards an applied cognitive science perspective in education". The paper has outlined the nature of cognitive science, and discusses the whether the brain metaphor and computing metaphor are relevant and adequate. It states that the concept of parallel distributed

processing, strengthened by the social construction of knowledge, provides powerful frameworks for the teaching and learning of basic school subjects.

Halpern (2002) showed that educational reform efforts should keep the knowledge about how people think, learn and remember in the centre in the paper "Cognitive Science and the Work of Reform". It suggests against lectures, pre-organized laboratory work and frequent testing. Knowledge about human cognition can enhance how much and how well students can learn, which can be used to redesign higher education. The paper talks about the gap between empirically validated theories and pedagogical practice. Lecture method, mostly used in college level courses has been identified as appropriate for recognizing a concept, not to understand or apply the concept in other setting. It has been found that cognitive psychology and learning theory have much to offer in guiding how higher education is designed and reformed.

Siegler (2003) in the study "Implication of cognitive science research for mathematics education" has drawn conclusions about a number of aspects of mathematics learning. It examines conclusions based on cognitive science research on some aspects of mathematics learning. The work informs us regarding how children learn particular skills and concepts, the obstacles encountered by them, and instructional practices that can produce greater learning. It advocates that successful teaching-learning depends on careful, detailed, analysis of the particulars of individual children learning particular skills and concepts as well as the particular procedures and concepts to be learned. Some of the pedagogical implications which can be drawn from the study are—understanding what children already know when they enter school, providing students with instruction and examples that help them learn the component skills, anticipating types of misunderstandings that most often arise in the learning process, helping students move beyond these misunderstandings, retaining cognitive variability (spontaneous feature of children's thinking), providing flexibility of choosing the strategy, attending to children's verbal and nonverbal gestures as indicators of their understanding and readiness to learn, attending to both cognitive and social variables (for co-operative learning), asking children to explain the correctness or wrongness of answers, etc.

In their paper, "Principles of cognitive science in education: The effects of generation, errors, and feedback", Metcalfe & Kornell (2007) found that the principles of cognitive science have the capabilities and prospects of helping children to study more effectively. However, their

transition from laboratory to actual learning situations has not always been tested. The studies reviewed in this paper address three interlocking questions in an effort to better implement a computer-based study program to help children learn: whether generation help; whether errors hurt if they are corrected and the effect of feedback. The findings reveal that generation helps, errors that are corrected do not hurt; and feedback is useful in verbal learning. These findings may help put cognitive scientists in a better position to put their principles in the service of children's learning.

Schunn (2009) in the paper "How kids learn engineering: The cognitive science perspective" argues that age is not a bar to learn engineering. What is necessary is proper environmental support. He stated four principles which support engineering learning. These are—engaging children in solving significant design problems from the beginning, making visible models to support design task, iterative design and redesign are better than single design cycles and providing sufficient time for exposure to engineering material.

Aykol, Sungur & Tekkaya (2010) examined the differences in the level of using cognitive and metacognitive strategy in science of 7th-grade Turkish students. They also explored the relationships between students' background characteristics (like gender, previous knowledge, socio-economic status) and their use of cognitive and meta-cognitive strategy and science achievement. Elaboration, organization, and meta-cognitive self-regulation strategy use were found to make a significant contribution to students' science achievement. Moreover, factors like prior knowledge, parents' educational level, number of reading materials at home, frequency of buying newspaper, availability of a separate study room and computer with internet connection at home were found to be related with cognitive and meta-cognitive strategy use and science achievement.

Roebers, Schmid & Roderer (2010) in their study "Metacognitive monitoring and control processes involved in primary school children's test performance" examined metacognitive monitoring and control processes in elementary schoolchildren's test taking behavior. They also explored the impacts of these meta-cognitive skills for the accuracy and the quantity of test performance. Results revealed that by the age of 9, children develop the ability of reliably distinguishing between correct and incorrect answers. This is indicative of well-developed monitoring skills. In case of control skills, 11- and 12-year-olds proved to be better able to

improve their test performance than the 9- to 10-year-olds. They were found to do this by selectively withdrawing answers that would have been incorrect.

Kachergis, Yu, & Shiffrin (2013) in their paper "Actively Learning Object Names Across Ambiguous Situations" investigated whether active learning is better than passive learning in a cross-situational word learning context. They also investigated the strategies and found that most learners use immediate repetition to disambiguate pairings. They also found that learners who repeat only one pair per trial perform worse than those who repeat multiple pairs per trial.

The study "Human Semi-Supervised Learning" conducted by Gibson, Rogers, & Zhu (2013) has been conducted on the assumption that most real-world learning scenarios are semi supervised. Semi-supervised learning situation refers to the classroom situation where learners is exposed to a large amount of unlabeled information from the world, along with occasional experiences in which items are directly labeled by a knowledgeable source. The researchers have used the equivalences between models found in human categorization and machine learning research to explain how the semi-supervised techniques can be applied to human learning.

Carlucci & Case (2013) in their paper "On the Necessity of U-Shaped Learning" have discussed about the necessity of U-shaped learning. U-shaped behavior has occupied a central place in the debate about learning models in cognitive science in the context of language learning (in particular in learning English past tense). They presented results about the necessity of U-shaped learning both in classical models of learning as well as in models with bounds on the memory of the learner. It has been found that for parameterized, cognitively relevant learning criteria, U-shapes are necessary for full learning power. The exception is only for few initial parameter values. They also discussed about the relevance of the results of this study for the debate about learning models as well as directions for future research in cognitive science.

III. Discussion

It has been found that a range of aspects of education have been addressed by the cognitive science researches. While some studies like Klahr & Li (2005), Schunn (2009) and Aykol, Sungur & Tekkaya (2010) have addressed the issue of making learning effective for science, mathematics and other basic school subjects as well as engineering, other studies like Glaser (1998), Kala & Ramadas (2001), Halpern (2002) and Metcalfe & Kornell (2007) have

advocated for extensive implications of cognitive science research in educational research, educational reforms and better learning. Apart from these, some studies (Kachergis, Yu, & Shiffrin, 2013; Roebers, Schmid & Roderer, 2010; Gibson, Rogers, & Zhu, 2013 and Carlucci & Case, 2013) have established that cognitive science can help in remote aspects of education like test-taking behaviour of the students, learning object names, metaphoring machine learning to human learning, usefulness of U-shaped learning, etc. It can be observed that cognitive science is capable of addressing issues right from specific to broader aspects of education. They have rendered the necessity of the concept of parallel distributed processing for frameworks of teaching and learning, importance of using cognitive and meta-cognitive strategy in science achievement, impacts of using metacognitive monitoring and control processes for the accuracy and the quantity of test performance, necessity of proper environmental support rather than biological maturity to learn engineering, relevance of active learning in a cross-situational word learning context, modeling semi-supervised learning in human beings and relevance of U-shaped learning in full learning power.

IV. Conclusion

Due to its young age, the repertoire of studies in cognitive science is small in size. The researcher found that most of the studies in cognitive science are relevant to neuroscience or have been conducted from the perspective of neuroscience. This fact is also supported by Gupta (2001) that three dominant trends can be discerned in cognitive science research—neurobiology of cognition, human neurocognitive architecture and cognitive technology. However, the recent studies have entered the realm of education and addressed various issues in education. The field of education has also witnessed a paradigm shift from behavioristic perspective to cognitive perspective for looking at different educational aspects. It implies that cognitive science researches can guide education to a better system. Though the available cognitive science researches are very well able to establish the implications of cognitive science researches in education, there are many further prospects for improvement in other aspects of education which may help in getting fruitful outcome of educational efforts.

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