

The Influence of Socio-Cultural Practices on Mathematical Cognition

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Abstract

Defining the constructs of cognition and culture as entirely independent of one another, one located in the individual and the other in the environment, is naïve. To understand educational activities, we must study them as they are imbedded in culture. Mathematics learning is no exception and it is also influenced by socio-cultural factors. In this paper, I hold onto this socio-cultural view of cognition and strive to understand the interplay between social, cultural, and historical elements and their attachment to cognitive development processes of mathematical understanding by examining several empirical studies. In the conclusion, I challenge the notion that fixed mathematical knowledge is contained in a pre-structured environment independent of individual and collective human activity. Then, I demonstrate some important characteristics that can be drawn from informal settings and applied to formal learning situations.

Introduction

Cognition is a complex phenomenon. It is not sufficient only to examine how knowledge is processed in the brain, but it is also important to be aware of other social processes in acquiring knowledge. For example, in a classroom learning situation, students will not only learn on their own, but they also interact with the teacher and/ or other students to negotiate the meaning of concepts. Therefore, human thinking and human social interactions are interconnected. As such, human thinking could not be separated into individual properties or traits. Instead, it is a socially mediated process. Human cognition is distributed among societies, artifacts, activities, and contexts. Language also plays an important role as a mediating device in this process. For instance, small children in their initial growing stages, use their own modifications to the terms in a language to identify persons, such as their mother, or concepts.

In this paper, I support this socio-cultural view of cognition and strive to understand the interplay between socio-cultural and cognitive development processes in mathematical understanding. To analyze mathematical activities using a socio-cultural view, I embrace the cultural-historical framework proposed by Cole (2005). A central feature of this framework is that the structure and development of human activities emerges through participation in culturally mediated, historically developed, and practical activities involving cultural practices; tools; and artifacts. For example, in the past, when the method of counting numbers was not known to humans, they used to count the members of their cattle by allocating a pebble following a one-to-one correspondence with each member. I also support the view that language and artifacts play mediatory roles in the socio-historical development process (Vygotsky, 1978). In this view, as children grow, they acquire the use of tools and speech through social interactions. The physical tools might be material artifacts such as calendars, calculators, and computers. In learning, a child might use a physical tool, such as a calendar, to represent a mathematical idea or a symbol, such as the use of numbers and counting.

Vygotsky explained the mediating role of tools in human thinking. For him, a physical tool changes the way a person interacts with his physical environment. The tool changes the structure of the physical activity in the same way as a mental tool changes a mental activity. Mental tools can be symbolic sign systems to represent mathematical ideas, such as counting

or measuring systems. These cultural artifacts are themselves the products of historical development (Scribner, 1985; Vygotsky, 1978). In addition to this Vygotskian view, I will take into account the assumptions behind *activity theory*, that is, cognition observed in everyday practice is stretched over, not divided among mind; body; activity; and settings. More exactly, if we are to study how humans acquire concepts, we should not separate and study their mental actions, but we should examine how they interact with other persons and artifacts in given contexts in order to construct the concepts in their heads.

In line with the above assumptions, in this article I examine the interplay between human mathematical activities and the role of culture; history; socio-economic; and political processes in non-formal education settings. To consolidate my arguments further, I will focus on a directed review of literature related to discrete empirical studies that were conducted in different cultural settings. Before reviewing and analyzing these empirical studies, I will clarify what the cultural-historical approach to study cognition is, situate this approach with respect to other cultural views, differentiate formal from informal learning, and address socio-cultural influences on mathematical cognition. Finally, I will present some ideas that can be applied to formal education to make learning more contextually meaningful.

The Cultural–Historical Approach in Cognitive Research

In a cultural–historical approach, learning occurs as a process within ongoing activities or a process involving culturally mediated and historically developed practical activities. In this approach, it is assumed that knowledge acquired through learning is not purely situated in an individual’s brain. There are different focuses in studying human cognition within a cultural historical approach. Cole (2005) stated that studying culture without positioning it in its historical context is vague, and the culture’s role in the mental life of human beings is important. He further argued that cross-cultural research conducted before psychology came into being does not adequately explain human cognitive development. Moreover, the strategies used in standardized cross-cultural research or multidisciplinary research on cognitive development also have the same shortfalls in explaining human cognitive development. Cole’s cultural–historical framework proposes a conception of culture that is in line with contemporary ideas of anthropology and cognitive science.

Lave (1988) presented a supporting view to this approach. She said that it is impossible to analyze education in schooling, craft apprenticeship, or any other form of learning without considering its relation to the world for which it ostensibly prepares people. Lave’s position was that these relations cannot be addressed within the social sciences today without a reexamination of the role of cognitive theory in explaining the effect of education on everyday activity. The bottom line of a cultural–historical approach is that individuals cannot be separated from their cultures, and they inherit their moments in cultural history.

Another notion of socio-cultural approaches is that artifacts, conventions, and interactions are all connected with cognition, and they should be examined intrinsically when studying cognition. Saxe (1991), a pioneer of this view, said that social conventions; artifacts; and social interactions are cognitive constructions, and they cannot be understood adequately without referring to individual cognitive development. He opposed the view that the constructs of cognition and culture are entirely independent of one another; one located in the individual and the other in the environment.

Saxe’s position embraces the constructivist view, which assumes that fundamental aspects of knowledge neither come from heredity nor from the environment, but are actively constructed by the individual through undergoing various social processes. How artifacts and forms of social organizations emerged over the course of social history is fundamental to this view. Further, microgenesis, or individual construction of knowledge constrained by culture, is taken to be the most basic driving force for all development and change.

This notion is seemingly a mixture of Piagetian and Vygotskian approaches to cognition. It emphasizes both individual’s active construction of knowledge and the enabling, constraining role of artifacts or cultural forms in forming and reforming human cognition. In the next section, I will compare and examine the role of culture in formal and informal learning contexts.

Formal and Informal Learning

According to Greenfield and Lave (1982), formal schooling happens in highly institutionalized places, such as school buildings, in many cultures. The activities that take place in that setting are very different from other day-to-day activities. Such activities are sometimes conducted by specially trained personnel. Further, these activities are formal and exist within a prescribed curriculum. In contrast, learning to cook happens in the kitchen, which is an informal setting and a space designated for cooking activities but not explicitly for educational purposes. Often, the person who teaches does not have formal knowledge of cooking. The person who is learning would learn by watching or by helping with activities.

In an informal learning setting, the enthusiasm of learners to learn could make them more motivated. Elaborating some inherent characteristics of informal contexts, Greenfield & Lave (1982) further said that when learning occurs informally, learners have more responsibilities in their learning. Also, they are more motivated, as they have a personal and cultural responsibility brought with them by tradition to learn. This motivation may also arise due to close contact with the teacher and the highly contextualized one-to-one instruction in this setting. Another factor for learner motivation could be the contribution that learners make to society. Learners may reckon learning as their responsibility and the outcomes of the process as byproducts of learning by taking part in adult activities. As the subject matter is highly valued and sometimes part of the cultural tradition in informal learning, the emphasis would be on accuracy leading to error-free learning, as well as possibly less room for new innovations. Therefore, the learning culture in informal education settings is a strong influential factor for learning.

Differences in formal and informal educational settings do not mean that there are no underlying themes that are common to both situations. Many practices in informal learning can be comfortably transferred to formal environments and vice versa. For example, increased learner responsibility to obtain knowledge and skills is a practice that can be transferred to formal learning. Learning by observation and imitation and teaching by demonstration are two other strategies that can be applied in formal education. Therefore, a discussion of these strategies using concrete examples in informal settings is important to get a sense of what can be transferred to formal contexts.

Socio-Cultural Influences to Mathematics Learning

The main purpose of this article is to conduct a directed review of literature about mathematics learning in informal settings. In particular, I will highlight and analyze the findings of five case studies. To situate this directed literature review within a theoretical position, I will take into account the influence of socio-cultural changes on mathematics learning. Moschkovich (2002) argued that learning mathematics can be seen as learning to carry out procedures and solve mathematical problems, constructing meanings, or participating in mathematical discourse practices. By citing two examples of bilingual mathematics learners' classroom discourse, she emphasized the need for looking at this discourse through a situated socio-cultural perspective. She stated that it is not adequate to examine learners' mathematical discourses to extract lexicons, but it is important to look at other aspects that bilingual learners use to communicate such as their first language; gestures; objects; and other artifacts.

Lampert (2001) argued that classroom discourse should focus on multiple representations of problem situations. This replaces teachers' authority to create better learning environments. Citing an example of arithmetic related to rates, she further claimed that we need a representation of the multiple levels of teaching actions as they occur in different social relationships over time to accomplish multiple goals simultaneously. These multiple levels could be a classroom as a unit of analysis, the role of artifacts and tools, and social interactions in learning. The time has passed when mathematics was considered to be culturally free (Masingila, 1994).

Mathematics Learning in Informal Settings

There are two emerging themes in the above discussion. First, an important factor of learning mathematics is the cultural context. Second, cultural artifacts play an active role in this process. Based on these views and other points of view in the foregoing discussion, I will examine some inherent cultural characteristics of learning mathematics in different informal situations with special attention to cultural context and the role of cultural artifacts as factors in this learning. Later in the

concluding section, I will make connections on how to apply these characteristics drawn from informal learning to formal learning.

Study 1 - Weaving Apprenticeship in a Maya Community of Zinacantan

There are various reasons for the changing nature of human relations within a culture. Greenfield (1999) argued that economic changes in societies transform human relations. She said that it is necessary to change socialization practices continuously for the next generation to participate in society, as the conditions faced by the next generation will differ from that of previous generations. Socialization is intrinsically future-oriented. It follows that changing socialization patterns is a key component of the psychological adaptation to social change. In non-industrial societies, many children are socialized to produce cultural artifacts through a process of indigenous education or apprenticeship that is related to behavioral and historical relationships between knowledge acquisition methods and cultural artifacts.

Greenfield conducted a longitudinal study of culture, learning, and cognitive development in Nabenchauk, a hamlet of the agrarian Maya community of Zinacantan. Weaving apprenticeship was utilized as a means to investigate processes of informal education, teaching, and learning in a society in which education does not traditionally take place in school. The weaving taught in Zinacantan in 1970 fostered the goal of cultural conservation. The instructional process was highly scaffolded and relatively error-free. Teachers, usually mothers, provided models and verbal direction in accordance with the developmental level of learners. Learners had little chance to err or experiment and innovate. The relatively conservative nature of disseminating weaving knowledge from mothers to children was manifested in the stable repertoire of woven patterns. Greenfield concluded that the goal of Zinacantan education and socialization was the intergenerational replication of tradition.

Greenfield further stated that an important shift in Mexican society was the transformation from a subsistence to a commerce economy. Under this system, Mexican farmers became entrepreneurs. This change in society brought new desires to people, leading to changed purposes and outcomes of the weaving industry. Following this, weaving education shifted from the transfer of traditions from teachers to learners to a discovery-oriented, independent, trial-and-error process. This shows a major change in the cognitive processes associated with learning, and the use of artifacts was influenced by the societal changes.

Study 2 - Computational Strategies of Youngsters in Recife, Brazil

An analysis of everyday use of mathematics by working youngsters in commercial transactions in Recife, Brazil, revealed that computational strategies used in informal settings are different from those taught in schools (Carraher, Carraher, & Schliemann, 1985). Performance on mathematical problems embedded in real-life contexts was superior to that of school-type word problems and context-free computational problems involving the same numbers and operations. There are reasons to believe that there is a difference between solving mathematical problems using algorithms learned in school and solving them in out-of-school contexts. This seems particularly likely with children who often have to do mathematical calculations in informal environments outside school when their use of algorithmic skills is inadequate, imperfect, or ineffective.

The study involved street-vending children, four boys and one girl, aged 9-15 years and ranging in level of schooling from 5 to 8 years. Four of the subjects had received formal instruction on mathematical operations and word problems in school, whereas one subject had not received this education. The subjects were asked to solve mathematical word problems related to trading in two situations. In one situation, the problems given were context-bound and in another occasion they were non-context specific problems. The results showed that children solved context-embedded problems much more easily than the ones without a context. Also, they solved the problems easily when the actual items in questions were physically present. Children failed to solve non-contextual problems but were able to solve the same problems in natural contexts. They were able to deal with problems involving quantities but they lacked the experience in manipulating symbols. In the formal test, where paper and pencil were used, children tried to follow school-prescribed routines without success. These results show the importance of the role of physical artifacts and context in mathematical problem-solving.

Study 3 – Candy-Selling in Brazil

Saxe (1988) carried out a study on candy-selling street children's mathematical understanding in Brazil. The mathematical understanding of 23 candy-sellers aged between 10 and 12 years with little or no schooling was compared to two groups of non-vendors matched for their age and schooling. The primary goal of the study was to document the interplay between children's developing mathematical understandings and everyday mathematical problems. Their performance was analyzed on three types of mathematical problems: representation of large numerical values; arithmetical operations on currency values; and ratio comparisons.

Results showed that despite the need to represent large values in their everyday lives, children, regardless of population group, did poorly on tasks requiring them to read multi-digit numerical values. Vendors and non-vendors had similarly developed nonstandard means to represent large numerical values. This was an expected result since problems involving large values emerge in the everyday activities of each population group. Children's ability to use bill values in arithmetical calculations was related to the nature of their everyday practices. The performances of the urban children were more adequate than those of the rural children, a result that points to the influence of participation in commercial activities. Most vendors, in contrast to non-vendors, had developed adequate strategies to solve arithmetical and ratio problems involving large numerical values, also an expected finding since these problem types emerge frequently only in the everyday activities of the vendor population.

Study 4 - Vendors' and Schoolchildren's Mathematical Procedures in India

In another study, Khan (1999) compared the mathematical cognition of learners in formal and informal contexts. Khan argued that mental phenomena do not exist in a vacuum. They are enmeshed in complex and intricately connected social, cultural, and historical processes. Even though psychology in the abstract allows us to derive laws of mental and cognitive functioning, it remains limited to a partial understanding of the mental processes of real people in a world that cannot be explained without its social and cultural history. Khan further said that by ignoring the sociohistorical contexts of our subjects and looking into psychological causes alone for the understanding of these phenomena remains incomplete and therefore impoverished.

Two groups of vendors and a group of schoolchildren in India were compared for differences in their knowledge of number systems and their competence with mathematical word problems. Statistical analysis revealed that vendors had a better understanding of mathematical principles and a better range of strategies than the schoolchildren, who were constrained by a narrow application of school-learned routines and algorithms. A lack of more conventional mathematical algorithms, however, reduced the efficiency of the vendors in solving problems.

The author evaluated the performance of all three groups in the contexts of the socio-cultural milieu within which they functioned. The study concluded that the vendors relied heavily on oral procedures whereas schoolchildren worked predominantly within a written mode when confronted with problems. The schoolchildren had trouble translating the problems into adequate operations and they were thus unable to solve them. On the other hand, vendors were able to understand and tackle the problems, but because they were working orally, they were unable to complete the process of computations when the numbers were large. In sum, rich contextual problems were found to be more suited for learning mathematics.

Study 5 – Mathematics Practice in Carpet Laying

Masingila (1994) highlights mathematical concepts and processes used by carpet layers for estimation and installation. As a study in the paradigm of ethnomathematics, it clearly indicates that mathematics does indeed have a cultural history. Masingila examined two mathematical concepts used by estimators and/or installers: *locating* and *measuring*. Locating involves exploring one's special environment and conceptualizing and symbolizing that environment with models, diagrams, drawings, words, or other means. Measuring is the act of quantifying for the purpose of comparison and ordering, using objects or tokens as measuring devices with associated units or measure words. Activity theory was used as a basis to address the relationship between knowing and doing.

The results showed that carpet layers developed fairly routine strategies to solve problems. Some problem-solving strategies were adaptive to a particular situation. They used four categories of problem-solving strategies: using a tool,

using a picture, checking the possibilities, and using an algorithm. They often used mathematical procedures and thinking processes that are quite different from those learnt in school. Also, these mathematical processes often reflected a higher level of thinking than typical processes in school. Sometimes, the problem solvers were unable to explain the procedures that they used, but they were certain that these procedures would work well. Moreover, they changed strategies according to their location of work. The carpet layers also used their intuition within the particular context of the problem to guide them to find a solution. Further, unfamiliar situations faced by the carpet layers, such as middle posts in the room, made them coordinate their mental activities to arrive at a solution. Therefore, the results indicate that mental activities in a problem-solving process are highly controlled by contextual factors.

Discussion

The socio-cultural dimension of the learning interface assumes that the object of research should be the historical and cultural setting with the learner in context, rather than the individual learner. Under this approach, learning has increasingly been studied as a cultural apprenticeship into community practices. This process is mediated by cultural tools and social processes, where culture has been theorized as a shared way of living within communities that is continuously being reconstituted through the use of cultural tools; technologies; artifacts; and concepts.

In this paper, I examined the literature on informal learning activities embedded in socio-cultural contexts to highlight the subjective nature of the learning process and its shared meanings. The studies explored above indicate how funds of knowledge are generated through the social and labor histories of communities. If these funds of knowledge are properly socially mediated with the assistance of more knowledgeable others, then this knowledge is even more valuable for use in formal education settings as well. For example, the weaving practice (study 1) shows the role played by artifacts as mediational tools in the changing process of human cognition. Part of learning mathematics is discovering patterns. The invention of new weaving patterns was highly influenced by societal changes, and this indicates how mathematical cognition is mediated by cultural tools and artifacts.

The computational strategies used by youngsters in Brazil (study 2) supports the thesis that thinking sustained by daily human activities can be, within the same subject, at a higher level than thinking out of context. The participants constructed novel understandings as they addressed problems that emerged in their everyday cultural practices. This understanding is linked to larger social processes and to local conventions that arise in practice. The candy-selling example (study 3) shows that when addressing socio-economic problems, children create new problem-solving procedures and understandings that are well-adapted to the exigencies of their everyday lives. The particular form that informal mathematical knowledge takes is the result of the interplay between the character of the mathematical problems with which individuals are engaged in everyday practices and the prior knowledge that they bring to bear on those problems.

The Indian vendors' example (study 4) also shows that cognitive and psychological functioning is deeply embedded in historical and socio-cultural contexts. Mathematics instruction in school follows a set routine based on a prescribed syllabus. Most often, people use their intuition embedded with contexts to guide them to find solutions to problems. Some of the procedures used by carpet layers (study 5) were highly contextualized. The procedure for determining the answers to their problems was sometimes not straightforward for carpet layers, and the inquiry displayed how intuition and context were used for problem-solving.

Recommendations

It is not possible to apply all the mathematical concepts that are used in informal contexts to formal contexts. Further research is needed to explore how teachers can build on out-of-school mathematics knowledge and include them in formal problem-solving situations to make learning more meaningful. The studies discussed in this article illustrate that many topics in current mathematics curricula could, and perhaps should, capitalize on contextual, informal learning to make material more meaningful and learner-friendly. Some topics for formal-informal mathematical learning might include money transactions, ratio and proportion problems, wholesale and retail trade transactions, as well as contextual geometric problems.

Mathematical activity, a distributed form of cognition, takes different shapes in different contexts. Each generation includes a set of cultural traditions, practices, belief systems, and thinking patterns. Changing socialization patterns may interrupt the socialization process that elders in a society had experienced as children. There is a tremendous capacity to develop new methods of cultural apprenticeships in changing societies. Rapid cultural changes also act as driving forces on most societies, and these changes need to be incorporated into learning processes. For example, rapid environmental changes have made the world more vulnerable to floods; tsunamis; landslides; earthquakes; and so on. The mathematics involved in forecasting these events in advance should be taught in schools. Also, cultural cognition requires a comprehensive view of the representational forms, such as visual; verbal; and kinesthetic, since there are different learning styles.

Arrangements of knowledge in the head correspond in a complicated way to the social world outside the head, and this knowledge is socially organized in such a fashion as to be indivisible. Our challenge is to interpret knowledge in the head together with its interwoven social processes. Cognition observed in informal education settings is distributed among mind, body, activity, or behavior. Studying cognition in practice within a situation, and looking at discontinuity between situations, will provide a basis for pursuing cognition as a nexus of relations between the mind at work and the world in which it works.

As well, both formal and informal learning occur at home, and parents are the teachers in this venture. The fundamental socialization processes that parents underwent in the past is different from that of today. Thus, parents might consider restructuring their goals to reflect current pressures in order to ensure that their children will be well prepared to participate in a future world that they might never know.

Furthermore, every individual is different. The creation of knowledge in an individual's head is not an isolated process from the social world. Learning is regarded as a contested process that is blind or non-consequential. Differentiated instruction and culturally challenging materials must get the highest priority in conceptual formation. Another potential problem today is that the situations where mathematics is used out of schools give meaning to computations, while mathematics, as it is taught in schools, has become mainly a process of manipulating numbers and symbols. To reduce this gap, problems that are embedded in a cultural context might be given a high priority in formal school curricula. The socio-cultural approach is a normative and ethical endeavor. It necessarily involves affording or constraining access to value-laden resources.

I further highlight learning as political, in the sense that it is mediated by institutional agents and social practices that may restrict access to learning opportunities for some individuals or groups while at the same time facilitating access to other group of individuals. Sometimes, the ingredients of the curriculum; textbooks; and other teaching materials are partial and favor certain groups in society. Segregating a curriculum into levels, such as applied; academic; or essential might deprive some individuals' access, and this might violate principals of equity. The relative power position of the individual in society has a greater impact on achieving learning opportunities. Sometimes individuals are subject to discrimination during the learning process. To make them confident in the learning process, it is important to emphasize the need for awareness of social worlds when individuals' construct their own knowledge.

The important questions for teachers who mediate this process is "Do children develop differently when socialization practices change?" and "How do we understand individual differences within these complex social boundaries?" The literature reviewed in this article suggest that teachers might consider further the broad social factors of learning when they teach children. It is difficult to predict how this process takes shape in society, as there are many interrelated factors. However, mediating devices such as language and artifacts play a prominent role in this process. As an example, group work placement in accordance with home languages might make students more comfortable and be immensely beneficial to them.

Lastly, what are the changes that researchers should make in their approaches to study human cognition? In a cultural-historical approach, culture is a situated resource; a fund of knowledge; and a repertoire of practices that learners draw upon to make sense of and participate in their social and material world. Therefore, human thinking cannot be separated from the social world within which it operates. Researchers adhering to this notion might embrace anthropological and ethnographic methods in research that move away from isolating individuals in order to study them. In this way, further investigations might also challenge notions of fixed mathematical knowledge as contained in pre-structured environments independent of individual and collective human activity.

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