The Development and Use of Information Processing Skills During Childhood and Adolescence

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Information processing skills first appear shortly after birth and continue to develop and adapt as the child grows. As teachers, it is imperative that we understand the development of these processes so that we can adapt our teaching to be developmentally appropriate, and so we can help children develop their information processing skills to their fullest. The chart below shows the ages at which these skills spontaneously appear and how children process information at certain ages. The discussion which follows explains the information processing strategies in greater detail and offers some suggestions as to how teachers can make use of them.

Chart 1: Information Processing Skills by Age Group

Theories/Strategies	Infancy	Early Childhood	Middle Childhood	Late Childhood/ Adolescence
Attention	No evidence of use.	Able to attend to highly engaging activities. Difficulty distinguishing relevant vs. irrelevant information.	Develop Selective Attention. Able to focus on relevant information.	Able to divide attention between multiple activities at the same time. Also use attention strategies strategically.
Automaticity	Unknown	Limited, but some very basic skills may gradually become automatized.	Gradual automatization of basic skills and information.	Continue to automatize new skills. Basic skills are automatized, allowing higher level thinking.
Memory Scripts-a mental representation of familiar, frequently encountered events	No evidence of use.	Used frequently by young children. May become upset if script is not followed or things happen in a different order.	Replaced by other methods.	Replaced by other methods.
Rehearsal Strategy-repeating information over and over to aid memory	No evidence of use.	Rarely used by children younger than 6. Used by 10% of kindergarteners.	Use increases as child ages. Used by 85% of fifth graders.	Still in use for some memory tasks.
Organizational Strategy-using relationships or groups to make information meaningful and therefore more memorable	No evidence of use.	Rarely used by children under 6.	Use increases as child ages.	Still in use for some memory tasks.

Elaboration Strategy- adding to information to make it more meaningful and memorable, relating information to previous knowledge	No evidence of use.	Rarely used.	Rarely used.	Primarily used by this age group.
Recognition Memory- recall is triggered by a stimulus	In use soon after birth.	Lifelong use.	Lifelong use.	Lifelong use.
Recall Memory- remembering without prompts or cues	No evidence of use.	In use, limited proficiency.	In use, more proficient.	Proficient, but often supplanted by retrieval strategies.
Retrieval Strategies- methods used to recover information	No evidence of use.	Use simple strategies, haphazard approach, give up quickly.	More complex strategies used, search memory more systematically.	Use systematic, complex methods and take time to recall information.
Prior Knowledge	No evidence of use.	Memory/recall ability depends on child's interest and knowledge, not age.	Memory/recall ability depends on child's interest and knowledge, not age.	Memory/recall ability depends on child's interest and knowledge, not age.
Metacognition	No evidence of use.	Children become more realistic about their limits in recalling information; recognize some tasks are more cognitively challenging than others; and recognize that certain strategies can aid in recalling information.	Children continue to master these skills through childhood.	Children continue to master these skills through childhood, which makes them more efficient learners.
Self-Regulated Learning	No evidence of use.	Limited to no ability to plan, set goals, organize, self-monitor, or self-evaluate.	Significant increase in the ability to plan, sequence, and set goals.	Progression is towards active strategies of learning. Adolescents continue to develop comprehension-monitoring skills.

Attention

In general, attention is the cognitive process of focusing on one thing while ignoring other things, such as a group of students working together in their group and ignoring what other groups are saying or doing (Attention, 2006). A child's ability to attend to a specific task is frequently used as an indicator of their cognitive maturity (Meece, 2002, p. 179). The most

famous definition of attention is from William James, who was one of the first major psychologists:

> "Everyone knows what attention is. It is the taking possession by the mind in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought… It implies withdrawal from some things in order to deal effectively with others." (Attention, 2006)

Good attention was formerly defined as the general mental capacity of a child, or their attention span. This attention span increases during the preschool years, but is still highly variable. Children tend to be less attentive when there are distractions in the room, or when the content becomes too abstract (Meece, 2002, p. 180-181).

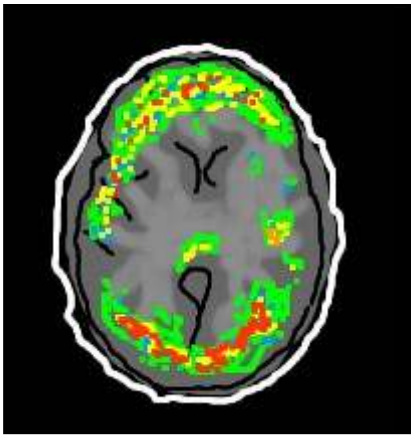
Current research defines attention as a set of behaviors and processes. Good attention involves "perceiving what is relevant to the task at hand" and "extracting information from ongoing events in an active, selective, and economical way" (Meece, 2002, p. 181). People in general tend to focus their attention on novel objects and fast changes, as they are more likely to carry new information (Collett). Children tend to have attentional preferences; for example, they may be drawn to an object based on its size, color, and shape. Younger children also tend to focus on how objects are similar, rather than how they are different. In general, most children are able to focus their attention in a planned, strategic, and efficient way by the time they reach adolescence (Meece, 2002, p. 181).

Although the ability to focus attention develops over time, around 3-5 percent of school-aged children have some sort of serious attention disorder. Attention disorders are a topic in and of themselves; however, educators must be aware of signs that a child has one of these disorders. Children with an attention disorder tend to display poor concentration, low sustained attention, and have problems with inhibiting impulses (Meece, 2002, p. 180).

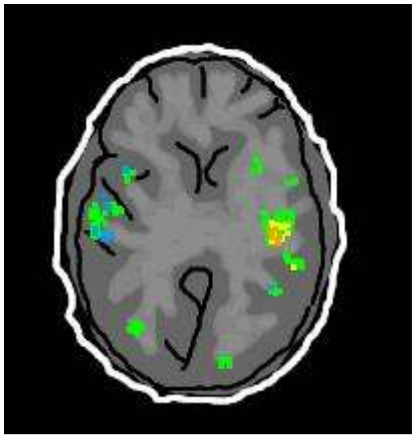
Automaticity

Meece (2002) describes automaticity as "a factor in the development of children's attentional process whereby familiarity with an object or task allows them to use it or perform without thinking" (p. G-2). It is also described as the ability to effortlessly complete everyday tasks with minimal interference from other activities occurring at the same time, and with no conscious thought to the step-by-step process (Collett). In other words, automaticity is the gradual elimination of attention in the processing of information (Meece, 2002, p. 182).

Automaticity develops over time as individuals become more familiar with an object or process. In the initial stages of learning, tasks are generally procedurally based and rely on a sequence of steps (Collett). These news tasks take a lot of effort, and are often difficult to do for long periods of time (Meece, 2002, p. 182). This processing makes heavy use of the working memory, which leaves little room for higher level thinking. As these new skills are repeated, the brain begins to recognize the situation and process the information faster with less effort. In a sense, this develops through over-learning. Once something has been over-learned, there is reduced demand on one's attention, reduced reliance on working memory, and plenty of room for higher level thinking (Perry, 2003). The picture below shows what the scan of a brain might look like when one is first learning a task and what it would look like once automaticity of the skill is acquired (Collett).



This is what an fMRI of the brain might look like before a skill is automatic.



This is what an fMRI of the brain might look like after a skill is automatic.

Although it seems backwards, cognitive processing in one's brain begins as a complex activity and then becomes simple (Perry, 2003). As children begin to acquire knowledge, fewer cognitive resources are expended in learning new information (Meece, 2002, p. 182). Children need repetition of skills and processes in order to develop automaticity. Once automaticity is achieved, that task can be completed without thinking of each individual step and other things can be thought about at the same time. For instance, a child first learning to play baseball needs to concentrate on how to throw a ball, but once they have learned this step, they are able to focus their attention on other aspects of the game (Collett).

Development of Memory Processes

The use of memory processes begins shortly after birth, developing and elaborating as the child matures and learns. Studies show that children's ability to store and recall information increases with age, and children spontaneously develop strategies to help them remember information. These strategies tend to appear at certain ages (see Chart 1), which is consistent with a developmental stage theory like Piaget's.

Very young children depend on what are called memory scripts, where they store information about everyday events as a sequence (Meece, 2002, p. 184). For example, a child might have a script for eating lunch where they sit at the kitchen table, put on a bib, are served juice and a peanut butter and jelly sandwich, and have a cookie for dessert. If the child's script is disrupted by being served lasagna in the dining room, he or she might become confused and upset. By the time children approach school age, they are able make complex scripts which they use to navigate through their day or retell a favorite story.

During the early elementary years, children shift from using scripts to other memory strategies. The first strategy to spontaneously appear is rehearsal (Meece, 2002, 185). Children repeat information over and over again as a way of fixing it in their memory. Studies have shown that children who rehearse information remember it better than their peers who are nonrehearsers. After learning to rehearse, the next strategy most children use is organization. Children divide information into meaningful categories as a way of making it easier to memorize. Piaget would consider this a form of assimilating information. Older children develop more complex ways of organizing, and are able to identify the main idea of a story and make an outline to aid their memory (ibid). The most complex form of memory strategy is elaboration. Organization involves recategorizing and interpreting information, whereas elaboration requires children to add to information to make it more meaningful to them, such as using a letter strategy or some other mnemonic. Spontaneous use of elaboration strategies appear much later in childhood than rehearsal or organization (ibid).

As children develop, their memory retrieval strategies become more complex and systematic. The most basic form of memory retrieval is recognition, where the child recognizes and responds to a stimulus (Meece, 2002, p.186). Newborn infants are able to identify the smell

of their mother's breast milk just days after birth, and five-month-olds can recognize objects as long as two weeks after seeing them (Meece, 2002, p.184). Recognition will be used throughout the child's life, but it will be aided by more complex strategies as the child grows and develops. A more complex form of memory retrieval is recall, where the child is able to remember information on their own without a stimulus or prompt. This requires greater mental effort and ability than recognition (Meece, 2002, p.186). As they mature and their mental sophistication develops, children create new strategies for searching their memory. These strategies include a more systematic and prolonged search or using a mnemonic device to encode and then retrieve the information.

The Role of Prior Knowledge

Although there is clearly a link between age and the ability to remember, studies have shown that the increase may be partly due to the child's increasing knowledge base. The more they know, the more easily they can organize (assimilate) new information. Meece uses a study by Michelene Chi comparing the ability of expert chess-playing children to that of adults who were unfamiliar with the game to remember arrangements of chess pieces (2002, p.187). The study showed that adults outperformed the children at other memory tasks, but the children were significantly better at remembering the chess pieces. Other expert-versus-novice experiments have shown the same outcomes, proving that prior knowledge is an important part of encoding and recalling information.

Metacognition

Metacognition is the term used to describe children's knowledge of their own thinking processes and cognitive capabilities; in other words, how children "think about thinking (Meece, 2002, p. 188), (Gallucci, 2005, p. 19). As he or she grows older, a child's understanding of his or her own ability to think and recall information changes in three ways. Children begin to recognize that there are limits to what they can remember. They also begin to understand that some learning tasks require more cognitive effort and are more draining than other tasks. Furthermore, children become aware that certain strategies can aid them in recalling information (Meece, 2002, p. 190). Through metacognition, children begin to understand which learning tactics work best, and continue to streamline their cognitive processes.

Self-Regulated Learning

As children become more efficient in their cognitive processes through metacognitive knowledge, they begin to take control of their learning activities. Children begin to use planning, monitoring, and evaluation strategies in learning situations. Around the time a child reaches middle school, he or she will use these strategies significantly more than he or she did in their early childhood (Meece, 2002, p. 190). As an example of how children progress in self-regulated learning, Meece cites how younger children tend to engage in passive strategies such as rereading assigned materials or copying text when asked to summarize a reading. In contrast, older children engage in active learning strategies such as highlighting key passages in order to remember their purpose. With time, older students become capable of connecting ideas and summarizing information in their own words, which make them more efficient learners (Meece, 2002, p.190).

One of the more sophisticated elements of self-regulated learning is comprehension monitoring. Students exhibiting comprehension monitoring are able to detect inconsistencies and confusion in their learning process and then make the proper adjustments to their strategy to rectify the problem (Gallucci, 2005, p. 19). Because of the sophistication of comprehension monitoring, this skill emerges in the middle school grades but continues to develop in adolescents (Meece, 2002, p. 190-91).

Implications for Educators

As educators, the first part of instruction is gaining the attention of students. It is imperative to create an instructional design that directs student's attention, helps them avoid distractions, and helps them avoid information overload. Some things to consider when thinking about instructional design are the complexity of the task you want the student to perform, the intensity of the working environment, and how the attention getting devices will enhance or distract the students (Papaila, 2001).

The spontaneous development of strategies is linked to developmental stages, but children can be taught to use more complex strategies. Research has shown that children can learn to use more advanced information processing strategies quite easily. Flavell *et al* showed that children who spontaneously rehearsed information remembered more than those who did not, but if nonrehearsers were taught to rehearse, they performed equally well (in Meece, 2002, p. 185). At all ages children can benefit from instruction in memory and recall strategies, although their age may limit their ability to apply the strategy as efficiently as an older child (Ford and Keating, 1981, p. 234).

As children progress metacognitively, a teacher's strategy must also progress. Teachers must always provide goals or guiding questions for their students, however, the rigidity of the teacher's "road map" should be determined in part by where their students are. Children that are metacognitively aware that certain strategies are more beneficial in recalling learned information than others find it easier to recall the information when it is transformed in a meaningful way. Conversely, those same children find it more difficult to recall information when someone else organizes it for them.

Teachers must approach their classroom in a way that encourages and incorporates self-regulated learning (Gallucci, 2005, p. 19) and reserve explicitly organizing information for "less-advanced learners" (Meece, 2002, p. 193). Elaboration strategies are an effective way to impose meaning on learning material for the students. For example, botany teachers found their class achievement went up when they began connecting course material to students' real life experiences (Wandersee, 2006). Meece provides an outline for a "community of learners," which is a school environment that encourages deep processing. According to this model, teachers must engage learners in the search for meaning and understanding; share in the development of the community of learning with the students; encourage reflection; and engage in research on central themes over a sustained period of time (Meece, 2002, p. 195).

Conclusion

A child's ability to process and retrieve information depends on many factors, including their attention span, automaticity, ability to apply and use processing strategies, their prior knowledge of a subject, metacognitive awareness, and their capacity to self-regulate their learning. All of these factors, not just the child's age, must be considered when planning

instruction. Additional studies show that there are even more factors influencing memory and learning. In a 2006 study, Lachman *et al* showed that an individual's beliefs about their ability to remember strongly influenced their performance on memory tests, whether or not they used strategies (p.378-379). Perhaps the most important thing we can do as educators is to convince students of their capability.

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