Comparing Novice and Expert Biology Knowledge

In terms of education, the need for students to develop beyond initial knowledge constructions and land at a complex, domain-specific knowledge structure is emphasized both in research and in application. Studying children's naïve biologist adds to our understanding of how teachers should address biology and science content (Inagaki, 1990). From the literature, we can predict the trajectory of a child's knowledge and inference structure, but the research describing expert's knowledge in contradictory. The purpose of this literature review is to highlight the main findings of research on the development of biology knowledge from novice to expert, while also highlighting the flaws in expert thinking. Researchers and educators may receive implications from this literature review that expert knowledge needs to be defined more explicitly, and educators should focus on addressing those parameters when teaching novices.

Definition of Novice Knowledge

Scientific thinking and naïve theories. A child developing his or her understanding of phenomena regarding how the world works (e.g., why the sky is blue, how gravity hold us to the earth's surface) before developing conceptions through schooling is developing what is called a naïve theory. Naïve theories have been studied in terms of domain-specific areas, specifically in biology, physics, and psychology, and in terms of development of scientific thinking, for which the goal is to generate hypotheses, collect evidence relating to the hypotheses, evaluate the evidence, and then make necessary revisions to respective concepts (Zimmerman, 2000). Scientific thinking is taught and used within the research process, but young children develop scientific thinking when they begin constructing naïve theories. Once a child develops a naïve theory about a specific phenomenon, he or she begins to collect evidence relating to the theory. Young children tend to collect evidence through either direct observation of phenomena or ideas they have heard from people in their environment, which may not always be accurate. In evaluating evidence, a child decides whether the evidence supports the theory they hold. The theory is strengthened if the evidence supports the theory for the child, but if the evidence does not fit the theory, the child will either modify the existing theory or discard the evidence altogether. The modification of a theory or concept toward a more accurate conception is known as conceptual change (Zimmerman, 2000). If the child possesses an inaccurate concept than never undergoes conceptual change, the result could be an adult with child-like misconceptions. Children may also possess conflicting conceptions of a topic, in which they actually believe one and then present the other teachers, if that conception is more accepted. It is important to gauge children's naïve theories in order to understand how knowledge develops. Before the literature on naïve theories emerged, researchers had to study conceptual change without knowing the start point for student's conceptions (Carey, Zaitchik, & Bascandziev, 2015).

Naïve biology. Naïve biology is defined as a child's hypothesis about biological phenomena and processes (Waxman, Medin, & Ross, 2007), and it stemmed from naïve psychology (Zimmerman, 2000). Piaget (1964) first studied children's understandings of living and nonliving things, which he deemed as illogical. Findings were replicated by Carey (1985), but she concluded that the children's conceptions were not necessarily illogical, but the conceptions were typical of children's development. Many researchers have since replicated Carey's (1985) findings and focused on how children's naïve biology develops from an initial theory to a theory that is more characteristic of adult-level understanding (Medin, Waxman, Woodring, & Washinawatok, 2010; Coley, Arenson, Xu, & Tanner, 2017). Naïve biology topics have also spanned into explanations of death, vital organ function, inheritance, and germs and illness. Coley, Solomon, and Shafto (2002) assert that understanding naïve biology is crucial to our survival as a species.

Studying children's naïve biologist has important implication for children's health education: understanding aids in predicting age of onset of autonomous health care routines and in explaining health disparities (Inagaki & Hatano, 2006). In terms of formal education, it is often the teacher's responsibility to check children's understandings. Children bring naïve theories to class with them, and when presented with conflicting evidence from information in formal schooling that does align with their conceptions, may reject the conflicting evidence. According to Inagaki (1990), there is an inattentiveness for teachers to assess students' naïve biologies, which hinders the likelihood of conceptual change and developing expert knowledge.

Definition of Expert Knowledge

An expert is defined as either someone who excels in a particular field or a professional who has achieved moderate success in his or her field (Boshuizen, Bromme, & Gruber, 2006). In terms of this literature review, both definitions will be used to reference expert and expert knowledge, as expert may refer to someone holding the position of professor or receiving a special degree, and expert knowledge may refer to organizing concepts in a more complex way, compared to novices. To become an expert, one would need access to both academic and professional knowledge; academic knowledge consists of the facts we learn through formal education, and professional knowledge consists of the skills we learn from field-specific experiences (Boshuizen, Bromme, & Gruber, 2006). Experts do not simply have more knowledge than novices, but they have a different way of structuring knowledge. Boshuizen, Bromme, and Gruber (2006) assert that experts perceive information differently, and to be an expert means to have a specific perspective about the domain, attributed to attitudes and experiences with domain-specific concepts.

The purpose of seeking the knowledge or status of an expert reveals itself in the definition. Excelling in a particular field to expert level is an accomplishment because the individual is assumed to have a vast amount of knowledge known to few people (Martin et al., 2012). This goal speaks more to the intrinsic motivations of the individual. The second goal associated with becoming an expert, achieving professional success in a respective field, is also obvious, as it assumes the expert has achieved some form of success. With both descriptions of being an expert, that individual will be referenced in the interpretation specific information because only they have access to it (Martin et al., 2012). Adding evidence to the difficulty in becoming an expert, Martin et al. (2012) assert that it takes roughly 10,000 hours of focused practice to perform on a level similar to experts.

From Novice to Expert Knowledge

The questions children ask are essentially the foundations to biological understandings. Children whose understandings of biology are developing more will ask more biological questions, while children who are not yet developing understandings of biological phenomena tend to ask more surface level questions. Young children tend to ask isolated, factual questions about biological phenomena, as they are still trying to understand the specific concept. In contrast, older children tend to ask explanatory questions because they are developing their concepts further and building on the knowledge they already possess. Children use various stimuli (e.g., actual objects, pictures of objects, toy replicas) to make sense of biological phenomena. Even though the stimuli tend to be adequate stand-ins for real animals, children often lose out on specific biological information, again focusing more on surface features.

Chouinard (2007) found that between 73 and 78 percent of questions asked by children, aged two to four, were information-seeking questions; however, children from age 3 to 3 years 9 months asked more biological questions when looking at replicas and drawings than other ages because they are just starting to develop their biological interests and understandings more, so they rely on gaining facts around representative stimuli.

Researchers tend to categorize children's naïve biologist into various thinking strategies, or construal's (Coley et al., 2017). A few common construal's are anthropocentric, teleological, and essentialist thinking. In anthropocentric thinking, students relate biological phenomena to humans because this thinking carries the assumption that humans are evolutionarily different from all other animals and inferences can be made from humans onto other organisms; for example, anthropocentric children are more likely to attribute a gene from human to animal, but not from animal to human (Carey, 1985; Coley et al., 2017; Marshall & Brenneman, 2016; Medin et al., 2010; Ross, Medin, Coley, & Atran, 2003; Siegler, 1989). Anthropocentric thinking stems from a lack of exposure to natural objects, which is typically replaced with abundant exposure to humans and explains their bases for inferences. Another construal is teleological thinking, which is characterized by focusing on the functional purpose of animals and objects.

For instance, teleological thinkers would see the only purpose of trees as serving as homes for small animals, ignoring the trees contributions toward maintaining the integrity of the atmosphere. The essentialist construal is characterized by the belief that an underlying essence is shared by members of a category, and the essence remains with the animal no matter what changes an animal undergoes. Keil (1989) found that children who use essentialist thinking were more likely to classify an animal they understood to be a raccoon as the same animal even after it was painted to resemble a skunk. The younger and non-essentialist-thinking children relied more on the animal's appearance, stating the raccoon had changed into a skunk. In essentialism, the variability that exists within species is ignored, and individuals assume that a quality observed in one category member will be observed in all members of the category.

The developmental trajectory of children's naïve biologist may begin with anthropocentrism in children as young as age four, but this is not a universal characteristic of all children (Medin et al., 2010). Coley et al. (2017) conducted a study that assessed the naïve biologist of eighth-graders and college undergraduates (biology majors versus non-biology majors). The researchers attempted to determine how naïve biological thought changed over time and how a formal biology education affected students' naïve biologist, or biological understandings. Anthropocentric thinking was measured by assessing the frequency at which participants determined if animals shared biological and ancestral similarities with humans, teleological thinking was measured by having participants report their level of agreement on whether stimuli existed only to serve a specific goal (Keleman, Rottman, & Seston, 2013), and essentialist thinking was measured by having participants determine if a physical change yielded a change in category membership. Coley et al. (2017) found that students' naïve biologies may persist into adulthood, which was evidenced by consistent levels of anthropocentric thinking across all three groups. While anthropocentric thinking was consistent, teleological thinking decreased over time and even more in biology majors. In contrast, essentialist thinking increased over time and in biology majors. The biology majors' high scores indicate that formal biology education may bolster essentialism, which may shed light on a flaw in biology education, as essentialism decreases attention to variability in species.

Fisher (1985) used free word-association to assess the growth of biological knowledge from fourth grade to college. The nature of the relationship between each stimulus-response pair was analyzed to test the relational links individuals possess related to biology-related concepts (e.g., animal, bacteria, photosynthesis). In free association, the first word an individual says is expected to be the link used most often. Younger children used more action words in their free associations; children from sixth to eighth grade exhibited more descriptive/classifying word associations; older participants—from age 14 to college-age—exhibited more superordinate, subordinate, and definition responses, which are characteristic of a more organized knowledge structure. Fisher found the participants' development of concepts and organization of knowledge was consistent with Piagetian stages of development and the notion that shared knowledge results from education, where students' knowledge begins to represent teachers' knowledge as the students' knowledge increases and becomes more complex and organized. This provides more descriptive evidence of novice biology knowledge and how we should expect knowledge to be organized and develop at specific ages. Fisher also found that in regard to memory, instead of losing episodic information related to learning a concept as the it develops, individuals retain both semantic and episodic information, but attend to certain aspects depending on their developmental stage. For instance, young children may use more unrelated, episodic details in describing a concept, while adolescents' access semantic facts to describe concepts.

Because of children's tendency to use movement, and the lack thereof, as criteria to inaccurately classify artifacts and nonliving, natural things and plants as living and as nonliving, respectively, Goldberg and Thompson-Schill (2009) assessed whether or not the misconception exists in adults (undergraduate, psychology majors and biology professors). Here, the goal for experts is to qualitatively differentiate concepts like alive and movement and animal and plant so they have accurate definitions of each and are then able to make accurate classifications The researchers found both college undergraduates and professors exhibit the same misconception as young children when differentiating between living and nonliving things, but the biology professors' extensive knowledge in biology lessened the difference in accuracy of classifying animals and plants as either living or nonliving. Even though the professors still possessed the misconception, they were accurate more frequently than undergraduates, which suggests that some conceptual change occurs as expertise increases. However, an expert may still possess misconceptions even after gaining a vast amount of knowledge and training in a specific domain. Tavares and Bobrowski (2018) evidenced another account of what may occur when a concept is not introduced and taught effectively from novice to expert knowledge construction.

The researchers found when assessing the acceptance and knowledge of the theory of evolution, undergraduate students in Brazil, on the latter end of receiving a specialist degree in science teaching, scored high in acceptance but low in knowledge. Beyond being surprised due to the undergraduates, who were to represent expert-level knowledge, scoring low on a knowledge assessment, the finding surprised the researchers because the theory of evolution is seen as being widely taught. According to science standards, one of the most universal and valid theories in the scientific community is the theory of evolution. Consequently, it is thought to be introduced early on by teachers and then extended over time. The results of Tavares and Bobrowski's study show what happens when a concept is not introduced and taught effectively: individuals considered experts may still possess misconceptions about foundational knowledge, conflicting with the development of more complex knowledge later on.

Conclusion

A child's initial understandings of both worldly and biological phenomena is critically important to understand, as it can have implications for research, the classroom, and our daily lives. Researchers have produced evidence to exemplify possible developmental trajectories for novice knowledge constructs, with the emphasis on achieving expert knowledge. However, expert knowledge can be as flawed as novice knowledge constructs. Researchers have also shown that experts have misconceptions similar to those of novices, and the abundance of knowledge they possess does not act as a counter to the misconceptions. Based on the evidence, it seems as though there is not much of a practical difference between the knowledge of novices and experts, at least in regard to biology. Because of this trend, more research should be conducted to assess specific misconceptions individuals must overcome before receiving the title of expert; additionally, research should be conducted to determine the effects of passing misconceptions from generation to generation, as this may have occurred while we have not yet investigated misconceptions "experts" may possess. In terms of practical applications for education, these results should emphasize the need for teachers to assess students' initial understandings and misconceptions of biology. Educators should keep in mind that consistently presenting students with accurate information and checking for misconceptions in-between is the most effective way of changing a child's naïve biology because these tools could aid in fostering conceptual change (Marshall & Brenneman, 2016).