Fifth and Seventh Graders’ Patterns of Understanding About Cells and Heredity in a Technology-Enhanced Curriculum

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Abstract: In this study, we explored fifth and seventh grade students’ ideas about heredity-related concepts and described patterns of understanding for these topics in the context of technology-enhanced curricula. Analysis of embedded assessments shows students progressed to more sophisticated levels of understanding, especially by reviewing non-normative ideas and integrating new content to their previous understandings. Students tended to struggle in distinguishing genes, chromosomes, and DNA and in connecting cell division with traits’ inheritance.

Introduction
To develop scientific literacy as it relates to genetics, students need to learn about cells and inheritance (American Association for the Advancement of Science, 2001; Tsui & Treagust, 2007). Research on students’ understanding of genetics and heredity shows that these topics are difficult for students to learn because they are complex and abstract (e.g., Lewis & Wood-Robinson, 2000; Tsui & Treagust, 2007). Students also have problems understanding complex genetic phenomena such as the relationship between genetic material and proteins (Duncan & Reiser, 2007). Since most research on students’ understanding of genetics has focused on the secondary level (Venville, Gribble, & Donovan, 2005), there is a need for research on students’ thinking and learning at late elementary and middle school levels (Duncan, Rogat, & Yarden, 2009). Our study explores upper-elementary and early middle school students’ ideas about cells, reproduction, and heredity and suggests patterns of understanding for these topics over time, through the implementation of a technology-enhanced curriculum.

Methods
Our cross-sectional, qualitative study was conducted in a socially and economically diverse, Midwestern, suburban school district. Fifth (ages 10-11) and seventh grade (ages 12-13) students worked with heredity curricula developed in the Web-based Inquiry Science Environment (WISE), a technology-enhanced learning environment. The fifth grade unit focused on helping students to distinguish inherited and acquired traits in organisms; understanding reproduction through plants; and learning that cells are building blocks of all living things. The seventh grade unit builds on what students learned in fifth grade to learn about cell molecules, structures, and functions related to inheritance —DNA, alleles, genes, and chromosomes, as well as the relationship between each of these concepts. The units included several online embedded assessments whose purpose was to capture students’ progress in learning the particular content of each activity, so that students could integrate their ideas into more sophisticated levels of understanding.

Student responses to online embedded assessments from both units served as our main data source. The responses of 90 fifth-graders and 54 seventh-graders were selected and analyzed using an open-coding procedure (Bohm, 2004). The iterative analysis of student responses resulted in definite categories of student understanding. Patterns of understanding were analyzed according to the knowledge integration (KI) framework, which defines student learning as the continuous addition of new ideas and the resulting reorganization of their personal knowledge (Linn, 2006). So, student responses were organized into two groups: cells and reproduction, and traits and inheritance.

Results
Along the fifth grade unit, students systematized their understanding of cells as the basic units that make up multicellular organisms and understood cells as units with some degree of specialization. They also recognized basic aspects of trait inheritance, namely that traits are equally inherited from both parents. Seventh-graders integrated the new content with their previous knowledge and provided more sophisticated and detailed explanations. Responses show that students were able to characterize cells by describing their genetic material, to explain the process of cell division and some of its implications, to distinguish between sexual and asexual reproduction, and to explain how traits are inherited at the cellular level. Students, however, tended to struggle in distinguishing genes, chromosomes, and DNA and in connecting cell division with traits’ inheritance.

We also analyzed embedded assessments designed to provide evidence of how students were reframing their ideas when they added new content to their existing knowledge. One of these assessments had students explain whether it is true that girls inherit most of their features from their mothers (or boys from their fathers).
Students in fifth grade used more varied explanations to respond to the embedded assessment (See Table 1). A group of students (13%) considered that this statement to be true, and their arguments were based on the common traits that they shared with their own same gender parent. Other students responded that the statement was false and their explanations consisted of giving examples of traits they shared with their opposite gender parent (32%) or simply paraphrasing the question statement (44%). Since the seventh grade unit introduced new topics of cell division and trait inheritance at the cellular level, students at this grade level tended to respond correctly (84%), providing more sophisticated and detailed explanations. In some cases, students included new concepts in their responses, for example, characteristics of sex cells, genes, alleles, and chromosomes (39%).

Table 1. Examples of student responses in 5th and 7th grade in a cross-grade embedded assessment

| Embedded assessment: Is it true or false that boys inherit more traits from their fathers than from their mothers? Please explain your answer. |
|---|---|
| 5th grade students | 7th grade students |
| True, because guys are taught everything by their dads like sports and stuff like that | It is false. All [offspring] inherit half of their chromosomes from their mother and half from their father, so there is an equal chance for boys to inherit more from their mother than from their parent. |
| I look like both of my parents but I think I look more like my dad than my mom. My face structure is more like my dads but my eyes look more like my moms eyes | False both parents put in 50 percent of the traits. The female holds the egg and the male holds the sperm which makes up 50 percent for each parent. |

Implications
When upper elementary and early middle school students experience coherent technology-enhanced, instructional materials over time, they are more able to explain and concepts that require the use of complex concepts of cells, reproduction, and heredity and did not maintain non-normative ideas described by previous research such as the belief that girls inherit only their mother’s traits and boys inherit only their father’s (Kargbo et al., 1980). However, students still struggled to distinguish among types of genetic material (e.g., Banet & Ayuso, 2002; Lewis & Wood-Robinson, 2000), especially when making connections among topics of cells and heredity in order to solve problems to explain complex phenomena, for example, some students’ responses were more fragmented, lacking adequate sophistication necessary to explain the implications of the meiosis process on trait inheritance. These findings can inform researchers and curriculum developers about areas where teachers need to scaffold student understanding, the range of student ideas, and the need to support students and teachers in connecting the different pieces of learning into sophisticated explanations.

References