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Describing Learning in an Advanced Online Case-Based Course in Environmental Science

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Educators increasingly embrace distance and online courses to compensate for lack of access to educational opportunities otherwise available in traditional school settings. Distance learning may provide particularly beneficial educational opportunities to academically advanced students attending poor or rural schools where access to advanced course options and gifted programs are limited, to students who cannot fit additional advanced courses into their school schedules, or students who are homeschooled or homebound learners (Olszewski-Kubilius & Lee, 2004). Due in part to the number of academically advanced students who lack access to advanced coursework and curriculum designed to meet their academic needs, some researchers are studying the efficacy of online learning designed specifically for these populations (Olszewski-Kubilius & Lee, 2004). At the same time, some suggest possible alternatives to traditional advanced coursework such as that found in Advanced Placement (AP) courses summary

Researchers increasingly embrace online courses to compensate for lack of access to educational opportunities otherwise available in traditional school settings. Researchers also recommend alternatives to traditional AP coursework to better meet the diverse learning styles and needs of advanced learners. These recommendations have particular applicability to students attending poor or rural schools where access to advanced course options and gifted programs are limited, to students who cannot fit additional advanced courses into their school schedules, or to homeschooled or homebound learners. However, little research exists on the use of online alternatives to traditional AP programs for students who lack access to advanced course options. This qualitative study investigated the learning outcomes for 138 students enrolled in an advanced online case-based course in environmental sciences. The course utilized problem-based and case-based learning methods and was developed using the guidelines provided by best practices for advanced learners and science pedagogy. Analyses of student online discussion boards, case resolutions, student grades, student and parent surveys obtained at the end of the course, e-mails, and AP examination results showed that many students enrolled in the course demonstrated learning, engagement, and challenge. Findings further support the conclusion that the course provided a viable learning alternative to traditional AP environmental science courses for many, but not all, students.

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that might be better suited to the specific needs and learning styles of many academically advanced learners (Hertberg-Davis & Callahan, 2008). Such alternatives are particularly appropriate for those from underserved populations. Problem-based and case-based curricula are suggested as promising possibilities (Stepien & Stepien, 2006). This article presents a study that examined the learning outcomes of an online environmental sciences course using a case-based and problem-based model designed for academically advanced learners.

Review of the Literature

Best Practices in Gifted Education

In creating and evaluating online courses for academically advanced learners, the first consideration is examining the principles that should guide their development. The National Association for Gifted Children (NAGC, 2000) articulated guidelines for creating curricular and instructional opportunities to meet the unique needs of gifted and advanced learners. These guidelines or "best practices" recommend: adapting, modifying, or replacing regular classroom curricula and instruction to meet advanced learners' unique needs; making the instructional pace flexible to allow for accelerated learning as appropriate; and providing differentiated resource materials (NAGC, 2000). Best practices further recommend studying a topic of interest deeply and with complexity, as well as using the rules, language, and tools of a discipline as professionals do to prepare advanced learners for future roles as professionals (Tomlinson, 2005; Tomlinson et al., 2002); providing experiences where students engage in creative thought and production in authentic or real-world settings (Hertberg-Davis & Callahan, 2008; Tomlinson et al., 2002); and emphasizing the development of higher order thinking skills (e.g., analysis, interpretation, synthesis, and evaluation) as exemplary objectives for advanced students (Gallagher, Stepien, & Rosenthal, 1992). As these recommendations suggest, multiple approaches to curriculum and instruction are necessary to meet the educational needs of advanced learners (Tomlinson et al., 2002; VanTassel-Baska, Zuo, Avery, & Little, 2002).

Many secondary schools adopt AP courses to address the needs of academically advanced learners. Some educators recommend AP courses because they offer excellent tests of talent strengths, and AP exams provide college credit for those students who score well (Hertberg-Davis & Callahan, 2008). The accelerated, rigorous curriculum experiences found in AP courses are appropriately challenging for many advanced learners. However, Hertberg-Davis and Callahan (2008, p. 205) notes the "'one-size-fits-all' curriculum and instruction" found in traditional AP courses offers minimal differentiation for individual learning styles, provides little opportunity for creativity, and, thus, is not always a good match for atypical advanced learners. Moreover, while a substantial amount of material is presented in traditional AP courses, the courses have been criticized because not much of the material is covered in depth, and they fail to provide authentic learning experiences (Callahan & Kyburg, 2005; Hertberg-Davis & Callahan, 2008). These limitations are particularly pronounced for advanced learners from minority, rural, and economically poor communities lacking the teacher commitment and/or student background skills necessary for success in traditional AP courses (Callahan & Kyburg, 2005; Hertberg-Davis & Callahan, 2008). Consequently, some researchers call for modification of AP courses—through, for example, scaffolded, problem-based, and collaborative learning—to better meet the learning needs of many underserved students (Hertberg-Davis & Callahan, 2008; Rodriguez, 1997).

Best Practice in Science Pedagogy

Best practices in science pedagogy align with best practices for academically advanced learners. The National Science Education Standards (National Research Council, 2000) posit "scientific literacy includes both science content knowledge (declarative facts and conceptual knowledge) and reasoning knowledge such as analyzing data, building explanations from evidence, and engaging with scientific questions" (Songer, 2007, p. 473). In other words, instruction should transform student thinking and learning from traditional, simple frameworks and surface approaches to more complex frameworks used by practitioners of authentic science (Toplis, 2007).

Best practices in science instruction further include inquiry-based learning, inductive thinking, and problem-solving activities in which students interpret experimental data, analyze case studies, and solve ill-structured, complex, real-world science problems (Heppner, Kouttab, & Croasdale, 2006; Prince & Felder, 2007; VanTassel-Baska, 1998). In studies by Tyler-Wood, Mortenson, Putney, and Cass (2000) and VanTassel-Baska (1998), advanced science curriculum incorporating higher level thinking skills and real-life science problems shows higher test scores on science assessments.

Problem-Based Learning

One instructional strategy that incorporates many of the best practices noted above for advanced learners in general and science students in particular is problem-based learning (PBL; Gallagher et al., 1992). PBL is an instructional method that places students in a carefully constructed learning environment "situated around authentic, ill-structured problems that require real world problem solving on the part of students" (Stepien & Stepien, 2006, p. 414). According to Hmelo-Silver, Duncan, and Chinn (2007), in PBL learning activities "students learn content, strategies, and self-directed learning skills through collaboratively solving problems, reflecting on their experiences, and engaging self-directed inquiry" (p. 100). Solutions to these problems are not formulaic. Students are expected to identify the information needed to solve a problem with or without the guidance of a teacher (Hmelo-Silver, 2004). Teachers are facilitators of resources, but are not the dispensers of information (Hmelo-Silver, 2004).

Because open-ended questioning techniques where no clear solution is evident characterize PBL, students utilize a variety of higher level thinking skills to solve the problem. Students both hypothesize about problem solving and predict short- and long-term consequences based on a clear understanding of content (Hmelo-Silver, 2004; Stepien & Stepien, 2006). Additionally, PBL requires students to analyze situations and evaluate information to solve problems in much the same way a practitioner in the discipline would (Gallagher et al., 1992; Hmelo-Silver, 2004). By offering such curricular experiences, students develop habits of mind resembling those of practitioners, thereby leading to lifelong learning and authentic skill development (Hmelo-Silver et al., 2007).

Research suggests the ill-structured nature of PBL is consonant with best practices in science education (Hmelo-Silver et al., 2007; Orion & Ault, 2007). A limited body of research suggests that PBL improves students' science skill development, conceptual understanding, knowledge retention, and ability to apply learned material to novel contexts in science (Prince & Felder, 2007; VanTassel-Baska, 1998).

Case-Based Learning

Case-based learning, a variation of PBL, also aligns with the best practices discussed above (Flynn & Klein, 2001). The case-based method is characterized by participatory and cooperative learning, as well as a focused study on a particular case with the teacher as facilitator. The case describes an "actual situation, commonly involving a decision, challenge, an opportunity, a problem, or an issue faced by a person (or persons) in an organization" (Erskine, Leenders, & Mauffette-Leenders, 1998, p. 2). Students utilize concepts and analytic skills to address the case presented and then discuss the case with cooperative peers. This distinctive discussion component aims to help students further interpret content and analyze information necessary for the solution to the problems presented by the case. Flynn and Klein (2001) asserted "cases make learning relevant and meaningful to the student through active participation in analyzing, discussing, and solving real problems in a specific field of inquiry" (p. 71).

Like PBL, the case-based method shifts the focus of learning away from rote memorization of content toward the application of concepts, theories, and techniques to solve real-world problems (Erskine et al., 1998; Flynn & Klein, 2001; Gallagher et al., 1992). It also provides critical learning experiences to move a student toward expertise in a discipline (National Research Council, 2000; Tomlinson, 2005), thereby offering an appropriate curricular opportunity for advanced learners.

Case-based learning has been identified as a best practice in science education wherein students study hypothetical cases involving questions or problems likely to be encountered by scientists. According to Prince and Felder (2007), "case-based instruction significantly improves student retention . . ., reasoning and problem-solving skills . . ., higher-order skills on Bloom's taxonomy . . ., the ability to make objective judgments . . ., the ability to identify relevant issues and recognize multiple perspectives . . ., and awareness of ethical issues" (p. 16).

The Efficacy of Online Learning

The National Research Council (2000) suggested that learning through real-world contexts is facilitated by online technology. Moreover, according to the National Science Education Standards, a central component of scientific literacy is the appropriate use of technology to support learning goals (Songer, 2007). Scientists do, and thus students should, use technology to develop content knowledge (e.g., deciphering complex ecological patterns) and scientific reasoning skills (e.g., analyzing data and hypothesizing based on scientific data). Further, video and computer-based learning connects learners with "communities of practitioners in science, mathematics, and other fields" (National Research Council, 2000, pp. 207–208), and with peers, experts, and/or educators in an interactive mode. Students in online courses exhibit higher achievement when a course strongly emphasizes online interaction; when students actively participate in online discussions, higher order thinking is enhanced (Jin, 2005). For advanced learners

> internet access provides wonderful connections to well-constructed units of study in science as well as ideas for

> teaching key concepts, and e-mail allows students to communicate directly with scientists and other students around the world on questions related to their science courses. (VanTassel-Baska, 1998, p. 4)

The National Research Council (2000) concluded "working with practitioners and distant peers on projects with meaning beyond the school classroom is a great motivator for K–12 students," and motivation has a positive effect on learning (p. 212). According to research summarized in the *Handbook of Science Research* (Songer, 2007, p. 474), using technology in science classrooms has been effective for guiding content development; improving hypothesis development and reasoning; analyzing historical data; organizing dialogue with peers and/or scientists toward collaborative understandings; scaffolding guidance in developing scientific explanations; and, providing guidance on reflection of steps taken and progress made within open-ended investigations.

Engagement and Challenge

Engaging and challenging academic experiences have also been shown to positively promote learning both for advanced learners and in science classes (Linn-Cohen & Hertzog, 2007; Olitsky, 2007). Engagement occurs when students grapple with concepts and tasks relevant to their lives (Milne & Otieno, 2007) and is characterized by high emotional energy, feelings of group membership, and a sustained interest in a subject (Olitsky, 2007). According to Skinner and Belmont (1993), "*engagement* includes both behavioral and emotional components. Engaged students show sustained behavioral involvement in learning activities accompanied by positive emotional tone" (p. 572, italics in original). Student behaviors said to be indicative of engagement "include persistence, concentration, asking questions, and contributing to class discussions" (Milne & Otieno, 2007, p. 525).

A high level of challenge promotes interest in learning, particularly among academically advanced students (Douglas, 2004; Olszewski-Kubilius & Lee, 2004). Factors contributing to a high level of challenge include rigorous and fast-paced assignments, independent assignments with facilitative—rather than direct—help from instructors, and assignments placing high demands on critical analysis, writing skills, reading, and questioning (Olszewski-Kubilius & Lee, 2004).

Advanced Online Courses

For many students, online AP courses can be challenging, support learning, and provide preparation for the AP exam (Olszewski-Kubilius & Lee, 2004). However, as more fully described in the methodology, the course developed for this study did not purport to be an online AP course, but rather an alternative and distinct advanced course in environmental sciences. Consequently, this study is more appropriately viewed as an extension of the research of Wilson, Litle, Coleman, and Gallagher (1997/1998), who found benefits for distance-learning programs in the areas of math and science for gifted high school students from rural areas. Although their studies support the viability of online learning for academically advanced, underserved learners, they do not address the efficacy of online learning courses designed to address both best practices for advanced learners and in science education, specifically those using case-based and problem-based learning methods. This paper focuses on the impact of the Environmental Science course developed using the case-based learning model applied to an advanced online course.

Specifically, the researchers use the data presented to answer the following research question: What are the learning outcomes for students enrolled in an online case-based and problem-based course developed using the guidelines provided by best practices for advanced learners and science pedagogy?

The Course and the Context

Project LOGgED ON (the Project) was a course conceptualized and developed by faculty, staff, and graduate students at the University of Virginia from both the Curry School of Education and the Department of Environmental Science. The Project developers endeavored to address the problem of access to highly challenging science curricula for economically disadvantaged, rural, or otherwise underserved gifted and academically advanced learners by creating, implementing, and distributing online case-based science courses appropriate for academically advanced learners. Notably, Project LOGgED ON's course in Environmental Science did not simply translate and transfer the College Board's AP Environmental Sciences course to an online format. Rather, the course was explicitly conceived as an alternative to a traditional AP course. Moreover, it was specifically designed based on research and best practices in gifted and in science education with pedagogy matched with online technology to create a case-based, interactive, engaging, and yet challenging course that could be used as an alternative to traditional AP.

In its conceptual phase, the course developers reviewed the AP Environmental Sciences syllabus from the College Board website. The purpose of this review was to examine and consider the topics covered by the AP Environmental Sciences course, but not to replicate it. The course developers from the School of Education also reviewed topics covered by nationally recognized college courses on the Introduction to Environmental Science. The Project developers then collaborated with scientists and Ph.D. candidates from the University of Virginia's Environmental Science Department to develop a novel Environmental Science curriculum.

The goals of the resulting curriculum were to (a) prepare students for advanced science studies by increasing knowledge and skill acquisition, (b) provide students with opportunities to communicate with peers, (c) write about advanced science topics, (d) work as independent learners, and (e) provide authentic experiences in studying science online. To achieve the goals, 16 cases were designed to include complex and interdisciplinary approaches to understanding the nature of environmental science. Topical units of study for the cases included essential concepts such as plate tectonics and the Earth as a dynamic system, human populations and their global impact, renewable and nonrenewable resources, environmental quality and sustainability, as well as environmental ethics and laws. For each topic selected, the case posed an authentic environmental issue or real-world environmental science problem to solve (e.g., pollution in the Chesapeake Bay or the advanced rate of global warming in Alaska) that could be approached in a variety of ways and for which there was no one "right" answer. Each case presented a short narrative assigning the students a role such as graduate student, intern, or researcher. At times, the roles were linked to a genuine organization with which the student scientist might participate (e.g., the Chesapeake Bay Foundation). These roles were intended to give students a perspective on the environmental problem at hand, to enable them to participate as one who endeavors to solve environmental problems, and to expose them to the role of an actual scientist grappling with environmental issues and problems. Through presentation of content, access to an expert video library, primary source references, and the use of open-ended questions, students were required to apply new knowledge to evaluate the issue presented, to explain why it presented a problem, and to use their scientific understanding to defend and support a proposed solution to the problem. Thus, while the resulting curriculum covered many of the topics contained in both the AP and university Environmental Sciences courses reviewed, it was not exhaustive of those topics and presented the topics in ways unique to the course.

Two textbooks were chosen to accompany the online course. One was a high-school-level textbook recommended by the AP College Board (Skinner, Porter, & Botkin, 1999). The other was a college-level textbook used in several college courses reviewed by the Project (Botkin & Keller, 2005). Students received both textbooks and could use either or both for each topic. The two textbooks allowed differentiation of learning styles as one was more conceptual and the other more scientifically detailed. Experts in environmental sciences participated through videos in a lecture format to create an expert video library. Furthermore, animated simulations were created to enhance learning experiences and ensure student understanding. All cases required advanced reading, note taking, lab work, a test and a quiz, and a final case resolution. In addition, students were expected to participate in online discussions with peers and instructors answering a series of open-ended questions, engaging in debate, asking questions, and reflecting on problems and issues posed by each case with other students. All work was submitted online.

The online format of the Project precluded science laboratory experiences common to students in traditional science classrooms, including those in AP Environmental Sciences courses. Therefore, the course required labs that students could independently complete in their own homes or communities. For example, one lab required students to research the watershed areas in which their homes existed. Some other examples included conducting water pressure labs using materials found in the home, researching the students' home energy sources, and making visits to their local landfills. Moreover, although environmental science experts lectured in the expert content videos, the course format precluded interaction with these experts.

As more fully described in the methodology, course participants consisted of a diverse range of students, including academically advanced students who lacked access to AP courses in their school environment. The course was taken independently as an extra course beyond the traditional course load, as a course for home-schooled students, and/or as a replacement course fulfilling a school science requirement. Online instructors provided ongoing assessments and feedback and graded students. Instructors based their grades on the assignments associated with each case, including lab write-ups, quizzes, tests, case resolutions, and online discussions. As described more fully in the methods section, many of the instructors were themselves experts in environmental sciences.

Project LOGgED On did not provide high school or middle school credit for the course. Rather, each participant's school determined how to weight the course and whether it would give credit. In making this determination, the schools reviewed the grades and feedback given by instructors. The Project obtained follow-up information from the participants' schools, which indicated all students who completed the course with a passing grade of C or higher received high school or middle school credit.

Method

Symbolic interactionist theory (Blumer, 1969), the studying of behaviors, actions, and interactions, provides the conceptual framework for this study. The methods and techniques of grounded theory research (Strauss & Corbin, 1988) inform the data collection and data analysis process for the purpose of deriving a theory surrounding the use of online case-based courses as an alternative delivery vehicle for advanced curriculum. The theory, as defined by Strauss and Corbin (1988), denotes "a set of well-developed categories (e.g., themes, concepts) that are systematically interrelated through statements of relationship to form a theoretical framework" (p. 22) that explain, in this case, the phenomenon of online learning. In attending to the tenets of grounded theory, it was our intent to garner results that would be reproducible by other researchers with a similar theoretical perspective given the same data set and following the same guiding rules for data analysis.

Participants

The Project offered the Environmental Science course during the 2005–2006 and 2006–2007 school years. Participants for the course self-identified from information about the course posted on state departments of education websites and letters to state and district superintendents. Advanced students who lacked access to AP courses in their school environment, particularly those students from rural and economically struggling communities, were specifically targeted in these postings. The course was described as an advanced online environmental sciences course, not as an AP course. In fact, the course description explicitly disclaimed that the online course was an AP course. Nevertheless, to incentivize participation in the Project, students were offered the chance to take the AP examination at the expense of the Project. Interested parties then contacted the Project to register for the course.

Notably, Project administrators did not limit participation in the course to identified gifted or advanced students or to high school students as is typical in the AP context, or to students from any particular ethnic or socioeconomic background. Thus, although the course purposefully sought the participation of students from traditionally underrepresented groups, no confirmation of socioeconomic status, racial or ethnic background, or prior gifted identification was specifically requested or received.

The 138 self-identified students ultimately participating in the course for both years came from 14 states and ranged in age from 12 to 17 years old. Several were homeschooled. Although the Project did not have specific demographic information for each individual student, information on the schools and school districts from which these students came was available. Based on a review of federal, state, and local websites for these schools and school districts, researchers for the Project ascertained that approximately half came from rural school districts, from school districts comprised predominately of minority students, and/or from school districts with a significant population of students receiving free and reduced lunches. Sixty-nine percent of the participants were juniors and seniors. During its first year, more than 150 students initially enrolled in the course, with 88 students ultimately participating. Of these, 60% were female and 40% were male.

Of the 88 participants in Year 1, 59 finished in good standing and received high school credit for the course, 54 students took the AP Environmental Science exam, and 17 received a score of 3 or higher. During Year 2, 63 students initially enrolled in the course, with 50 ultimately participating. Of those, 41 students finished in good standing, 25 reported scores on the AP Environmental Science exam, and 7 students reported scores of 3 or higher. In total for Years 1 and 2, 31 students received a 1, 24 students received a 2, 13 students received a 3, 9 students received a 4, and 2 students received a 5 on the AP exam.

Instructors for the course were recruited through flyers at science education conferences and science educator websites. The Project specifically sought instructors with extensive science education backgrounds, online experience, and experience working with advanced and gifted students. Prospective instructors were interviewed prior to being hired. Sixteen instructors were hired, 13 of whom had doctoral degrees in a science field and were considered to be experts. The remainder had master's degrees in science education.

Data Collection

The 138 students who participated in the course are included as units of study. Data collection began at the onset of the project and included grades, enrollment/completion statistics, surveys, e-mail correspondence, course discussion board entries, case resolutions, and AP scores. All qualitative data were compiled, organized, and entered into nVivo (2007/2008), a qualitative software program, with the threaded discussion boards comprising the bulk of the data. A total of 738 threaded student discussions generated by and responding to questions posed by the 5 cases were analyzed. Each discussion averaged 18 replies, resulting in a total of 13,284 entries which were read, reread, and coded. Additionally coded were 54 student case resolutions (the final project for each unit of study), as well as the open-ended responses to a student survey. The student survey was completed by 35 students and consisted of 58 comments. E-mail correspondence from students, instructors, parents, and school contacts were also included in the data set.

All of the data were systematically processed using the tenets of grounded theory methodology through the use of open coding, axial coding, reflective memo-writing, and theory development. Each year's data (2005–2006, 2006–2007) were coded separately to allow the codes and hypotheses developed in Year 1 to be tested or grounded on the data for Year 2. Year 1 codes and emerging theory were rigorously examined for confirming and disconfirming evidence on the data set for Year 2.

Process of Analysis

Analysis was carried out by a team of Project researchers including the project director, a data analyst, and three graduate research assistants. No one on the research team or data analysis team was a course instructor, which eliminated a potential area of bias. Three researchers have a specialty area in gifted education, one in qualitative methodology, and one in instructional technology. Two are also experienced educators with more than 20 years combined experience working with gifted students at the middle and high school levels.

Once the data were funneled into nVivo (2007/2008), open coding was performed on several discussion board sections. In this early phase, two researchers "discovered" the following categories within the data: (a) factual content, (b) student-instructor interactions, (c) student-student interactions, (d) asking questions, (e) background knowledge, and (f) higher level thinking. Due to the depth of the data corpus, the researchers concluded that the data set would need to be constrained. Selective sampling resulted in 5 of the 14 cases in the course to be used in the analysis. A description of the selected cases and reasons for their inclusion are illustrated in Table 1.

Using these cases as the focus, the researchers worked to further define and refine the codes. The emerging codes were constantly compared against the new data as they were reviewed, and new codes would often emerge and be incorporated into the developing coding scheme. For example, the code "passion" came into use near the end of Year 2 when it became apparent that there were degrees of "interest," "enthusiasm," and "value" that needed to be captured into a separate code. This code, "passion," became pivotal in the development of the theory around engagement. Researchers documented the definitions for the codes as seen in the examples in Table 2.

This was an important step to make sure that the codes were applied to all of the data in the same way. To promote coder agreement, each team member independently coded a section. The team then met to discuss results and refine code definitions.

Table 1

Cases Included in the Data Set

Name	Description	Reason for inclusion
Case 1: Black Smokers	In this case you have been hired as a pilot in training for the submersible vessel, the Alvin. The Alvin is a small vessel that will be used on an expedition of deep sea vents along the Galapagos Rift. This case highlights key concepts and topics in the field of oceanography, including: ocean plates, sea-floor spreading, geothermal vents, energy sources, underwater exploration, and adaptive responses of organisms to abiotic conditions.	This is the first case. It was selected to gain knowledge of the beginning skills and interactions of the students.
Case 6: Trouble in Paradise	In this case, you are a researcher with the National Parks Service, investigating the effects of invasive species on the Hawaiian Islands. This case highlights key concepts and topics in the field of ecosystems, including: ecosystem, balance, and exotic/invasive/nonnative species.	Randomly selected from Cases 2–8
Case 9: Baking Alaska	In this case, you are a research assistant working with NOAA. You have been assigned to write an evaluation of the impact of human development on climate and global warming. This case highlights key concepts and topics in the field of atmospheric science, including: global warming, carbon dioxide, greenhouse gases, water and ice, scientific controversy, and modeling.	This is the middle case, selected for tracking progress and because it had a different terminal assignment (position paper).
Case 10: Open Dumping	In this case, you are an EPA employee who has been assigned to assess the open dumping issue in a Native American reservation. You are then charged with the task of making recommendations for potential pollution control in both urban and rural areas. This case highlights key concepts and topics related to waste disposal, including: litter, landfill, open dumping, groundwater, incineration, recycling, and ecosystems.	Randomly selected from Cases 9–14
Case 13: Saving the Bay	In this case, you are an undergraduate researcher at a research site on the Chesapeake Bay in Oyster, VA. Your research deals with the big question of how should we manage such a large watershed to control the inputs of nitrogen and phosphorus? This case highlights key concepts and topics in the fields of hydrology and ecosystems, including: surface water run-off, eutrophication, nonpoint source pollution, point source pollution, and ecosystem upset.	This was one of the last cases and was selected to examine the performance of the students near the end of the course.

Table 2

Sample Codes and Their Definitions

Code Names	Code Definition
Combining concepts	When students bring concepts together such as evolution and derivatives learned in calculus, weather patterns, and physics vectors, and when students make connections to either more detailed information or to a big picture or idea.
Bringing in their own experience	When a student refers to learning done outside the course (e.g., summer program, TV, field trip, his or her own reading): "Hey, I saw this IMAX once . . ." "I learned while researching bears . . ." "In chemistry class we . . ."

This exercise was repeated until all coders aligned on the application of the codes and again after a month of further coding. The project manager spot-checked the coding in progress and provided feedback to the coders. Periodically, coding reports were created and the data recoded by a different coder. This process helped refine the codes. Some codes were expanded and others compressed. For example, the code "opinion" was further broken into the codes of "stating an opinion" and "supporting their opinion" to capture the nuances between the two (with "supporting their opinion" showing deeper analytical skills), and the code "using the nature of science process" was collapsed into "thinking as a scientist" because scientists use the scientific process. In all, four iterations of the coding process were required to reach inter-rater reliability of 90% (Miles & Huberman, 1994). Remaining differences generally involved the degree to which the data reflected higher level thinking.

Coders also created methodological memos capturing their thoughts and concerns about codes as they arose. For example, one coder noted:

> In Section 3's discussion questions, I struggled trying to differentiate between thinking like scientist and nature of science coding [NOS]. When I saw both hypothesizing about science concepts, plus something concrete in getting

> more answers (a proposal or plan) I went with NOS. (methodological memorandum, November 21, 2007)

These memos were discussed during weekly meetings and became part of the data set used in the final analyses. Coders also wrote reflective memos after each discussion section and again after each case in order to capture the researcher's thoughts, interpretations, and beginning analyses. These reflections were shared and discussed. In this way patterns and themes emerged. The emerging theme of learning and engagement reflected here later found a home in the final theory reflected in the Appendix. This iterative process can be seen in the following reflection:

> I've looked through all of my reflections. My overall sense of how we did is that many students exhibited learning, engagement, and creativity. I saw many of them having interesting debates and conversations about the cases specifically. I saw them demonstrate their learning through their recitation of facts and learning, and their application of those facts to problem solve. Their engagement was apparent particularly when they had first hand experience with, or deeper knowledge of, the issues presented by a case. Thus, their engagement seemed particularly apparent in Open Dumping and Baking Alaska. (analytic memorandum, April 6, 2008)

Results

The results reflected in the final theory (conclusions) were derived from integration of the codes from student discussion board data, student grades, researcher reflections and memos, and student and parent feedback. The results reflect representative data analyzed.

Evidence of Learning

As revealed in the codes, and as set forth in the Appendix, the case-based and problem-based nature of the Environmental Science course promoted learning for many students. More than 3,700 student comments were coded under the heading of learning in the discussion boards alone. Learning was reflected through the acquisition of scientific facts and vocabulary, evidence of student engagement in higher level thinking, and when students evaluated cases as practicing scientists would.

Factual content. Data evidencing the use and understanding of relevant scientific vocabulary were coded under "factual content." Almost all students showed factual content knowledge. This is true even for students who did not show significant evidence of higher level thinking or who did not receive an A or B in the course. Thus, the quality of responses coded for factual content ranged widely, with some students exhibiting deeper knowledge and understanding of the facts than others. The following data constitute representative examples of factual content knowledge concerning the Chesapeake Bay, as well as the variety in the quality of student responses addressing those facts. An example of a comment coded "factual knowledge" that lacked a showing of deeper knowledge was "I learned about hypoxia in the Chesapeake" (student comment on online discussion board, April 4, 2006). A more fully developed response demonstrating factual content knowledge was "the plankton population gets too many nutrients, they mass reproduce, the nutrients stop, they starve, it takes up oxygen, and fish die. That is basically the problem" (student comment on online discussion board, April 2, 2006). Another student demonstrates deeper factual knowledge through her use of the vocabulary of scientific phenomena and more detailed knowledge of such phenomena:

> In this case, I learned about the problems facing the Chesapeake Bay ecosystem. I learned about the Freshet and the overabundance of nutrients it brings to the ecosystem. This causes algal blooms that threaten other

> organisms in the ecosystem. This is mainly a problem for the sea grasses that grow at the bottom of the bay. The problem is exacerbated by the decline in population of the American oyster, the population of which used to be so great that it could filter water of the bay in 72 hours. I also learned about hypoxia, anoxia, thermoclines, haloclines, and pycnoclines. (student comment on online discussion board, May 2, 2007)

Finally, another student exhibits firm command of factual content and uses her knowledge to demonstrate understanding of the scientific phenomenon at work:

> Hypoxia: it reminds me of chicken pox. Oh gross! Albeit for the plant life, it really is a kind of sickness: a slow death of suffocation that hits in the summer in the deepest regions of water bodies. Many animals in lakes need oxygen for the reactions their bodies use to survive. That oxygen can easily become scarce and the chemical makeup of lakes and the animals that live there can be easily altered. The first place that feels Hypoxia's effects is the bottom, where sediments and water meet. Because the amount of oxygen used in decomposition, which is greatest at this interface, is high (and highest in the summer), organisms there feel the effects of Hypoxia first. In addition, springtime phytoplankton die in the summer, sinking to the bottom and suffocating the "bottom-life." So, if you're looking to be "hypoxiated," the summery depths of a lake are the perfect place! (student comment on online discussion board, March 1, 2006)

Higher level thinking. Many students exhibited a variety of higher level thinking skills, which further supports the conclusion that they learned. Exactly 1,450 comments were coded under "higher level thinking." Generally speaking, data were coded for higher level thinking when students understood the "bigger picture," and took the facts learned from a case to a higher or more imaginative, analytical level. More specifically, data for higher level thinking included the following: when students "combined concepts" such as evolution or economic theory in their comments; when students made "connections across cases" or referred to ideas or topics from other cases; when students made "connections to other content" previously learned in other areas of studies such as physics or history; when students engaged in "questioning," which pushed their online classmates to more deeply analyze the cases; and, when students brought in their "own experiences" to illustrate or explain their thinking. For example, the following comment revealed higher level thinking in the Black Smoker case by stating "on a more serious tone, that is rather ironic that we know our own planet less than our moon" (student comment on online discussion board, November 8, 2005). Similarly, the following student incorporated questioning and combined historical concepts to show higher level thinking:

> When do you think we became invasive species? Were we an invasive species when we were hunter gatherers? Did it start when irrigation and agriculture started? When the first small towns and cities were developing into cities from today? Perhaps when we inhabited Northern Africa and the Fertile Crescent? Maybe when we spread to Australia? Surely, we did not start out as an invasive species, so when exactly would you say we became one? I do agree with you, though, that humans are an invasive species, though there is no way we are going to leave any ecosystems alone. Humans are curious and greedy by nature; unexplored land is adventure and money waiting to be taken. (student comment on online discussion board, February 7, 2006)

This student drew on prior historical content knowledge to demonstrate understanding and amplify a scientific point:

> In a sound ecosystem, it seems things will evolve much more slowly. In this way, it makes a habitat such as the

> islands of Hawaii more defenseless against invasive species. I think that Darwin's working on an island probably helped him because the species in the ecosystem were isolated. This allowed him to view a much slower but more evenly-paced process of evolution. It would be harder in an area in which evolution was more sporadic due to the introductions of exotic species. (student comment on online discussion board, February 7, 2006)

Yet another student incorporated her own life experiences into her analysis of how to solve the problem of open dumping:

> I do agree that moving the contaminates from the open space to a landfill is the first thing to do, and that salvaging anything recyclable is a must. To solve this case, however, I think more analysis of human habits is paramount. We need to know the differences between the actions of those in rural areas and those in urban areas and their feelings/needs in order to be able to predict their actions. My own experience of living in a rural community is that people have a lot of room and feel free to do as they please. They also have a strong sense and need for ownership and freedom of their land, you know. Since the case wants us to make recommendations for pollution control in urban and rural areas, we really need to understand the education level, personal goals, and overall motives of people in each area. Then, we will be able to see why they do the things they do and offer more precise and appealing alternatives. (student comment on online discussion board, February 1, 2006)

Finally, another student made connections across cases to show higher level thinking:

> A second alternative is incineration, which is the burning of combustible waste at temperatures high enough to consume all combustible material, leaving only ash

> and noncombustible to dispose in the landfills. The idea of incineration is the reduction of volume of waste conditions, but also contributes more to pollution than taking away. The noxious fumes coming from incineration seep into the air and pose a threat as well. Smokestacks from incinerators may emit oxides of nitrogen and sulfide, which cause toxic acid rain, explored in Case 07, Smog City, and ozone depletion. Others cause emissions of carbon dioxide, which relate to Case 09, Baking Alaska, and the threat of global warming. In the end, incineration causes more problems than reducing them. (student comment on online discussion board, January 25, 2007)

These selections are representative comments coded for higher level thinking.

Thinking as scientist. Many students used the rules, language, and analytical tools of the discipline of science to demonstrate learning. These comments were coded under "thinking as scientist." This code was further broken down to distinguish when students (a) simply stated "opinions," (b) "supported" them with scientific facts found in the cases, and (c) used the "nature of science process," or scientific inquiry and methodology, in their comments. Together, 1,408 comments were coded under "thinking as a scientist." The following examples show students both stating and supporting their opinions, and in so doing demonstrating scientific knowledge and understanding. A representative comment coded under "opinion" is "I think the legislation is a great idea, but since not every state on the watershed signed the agreement, it will be hard to regulate the pollutants entering the bay" (student comment on online discussion board, March 11, 2007). The following two comments were coded as "supported" because they provided justification for their opinions:

> Yes, I think that open dumping in the ocean is awful. I actually think that it is worse than open dumping on land. This is because the water can spread more rapidly and evenly throughout the entire ocean. On land, the water

> takes a long time for it to move underground. (student comment on online discussion board, February 20, 2006)
>
> This is strictly my opinion, and I think someone mentioned it before, but I believe that if we can control the amount of NEW invasive species coming in, with the help of Mother Nature the ones that are already there will somehow manage to find a balance. We have already seen in our last few cases that the environment has an amazing way of fixing itself if people will just stop causing the problem and making it worse. (student comment on online discussion board, December 7, 2005)

The next comments are representative of those receiving a "nature of science" code because they reflect the scientific inquiry method and contain proposed research questions:

> A piece of useful information would be how deep below sea level do scientists plan on taking the Alvin. Knowing this would determine how much water pressure should be expected and the temperature of the area where Alvin has gone. Also, knowing exactly what scientists are looking for can save time while under the sea. It also gives scientists an idea of what equipment, and how much, is needed to contain specimens obtained for studying. The last thing that scientists want is to contaminate any sea life that could provide vital information about ocean floors, sea floor spreading, geothermal vents, energy sources, etc. (student comment on online discussion board, August 30, 2005)
>
> Me again, I just wanted to clarify some of the topics I discussed in the last response. I do already know that the concentration of the sulfur expelled from the hydrothermal vents is a necessary energy source for the chemosynthetic bacteria, which are the support of these life forms such as the tube worms or the giant clams. I

> was presupposing, what if the animals that inhabit the Galapagos Islands were also altered by the hydrothermal vents, in the same manner as the ones in which we know were altered? Another thought just hit me as well. What if scientists could harness this sulfur or chemosynthetic for beneficial purposes? If they studied both the hydrothermal vents as well as the organisms they have effected, perhaps the knowledge could be used for practical use. (student comment on online discussion board, September 15, 2005)

Overall, these student learning comments reflect a successful endeavor to practice in the discipline of environmental science as practitioners. Students used scientific processes to analyze the cases studied. Moreover, they made connections across cases and to other content, and thereby utilized higher level thinking skills in the manner contemplated by best practices for gifted and science education. From such comments, deep and meaningful learning was evident.

Grades, survey results, and AP scores. Evidence of learning can also be found in student pass rates for the course, student survey results, and, to a lesser extent, AP exam scores. Of the 138 students who participated, 100 finished in good standing by passing the course and received high school or middle school credit for the course. Although only 34 students responded to the survey administered at the end of the course, these responses further support a finding that learning occurred. The majority of respondents (97%) agreed they learned something new about environmental science; 91% agreed the cases were useful to their understanding of content; 55% agreed they learned something about problem solving; and 31% agreed the course prepared them for the AP exam even though that was not the central purpose of the course. As the survey responses were anonymous, the researchers are unaware of which students completed them.

Results from the AP examination are mixed. Fifty-nine students did not elect to take the AP examination, including many who did well in the course. Of the 79 students who took the AP exam, 30% of them earned a score of 3 or higher. This is less than the national rate of 50% earning 3 or higher on the AP Environmental Science exam (College Board, 2006a). However, this course did not teach to the AP test, did not purport to be an AP course, and did not incorporate AP test preparation. Nevertheless, overall the AP test results offer the least support for the conclusion that the course promoted learning.

Evidence of Engagement

Significant evidence of engagement was also demonstrated by many students, which buttresses the conclusion that learning occurred in the online case-based course. One thousand nine hundred fifteen online discussion board comments were coded under "engagement." Engagement was revealed in many ways as reflected by its breakdown in the coding. Data reflecting "passion," or where a student showed high emotional interest in environmental issues, permeated many of the discussions. Similarly, numerous examples of students expressing the need to involve neighbors, communities, and governments in environmental causes (coded as "outreach") existed. For example, the following comment shows a student's high level of passion for environmental science (as well as the incorporation of historical concepts, which supports the "combined concepts" code):

> I will leave you with one last thought. In thinking of how to express myself clearly I make the analogy of humanity in the environment and humanity in communism. (Bear with me.) I have recently read The Communist Manifesto by Karl Marx and Frederick Engels. In it a utopian society is outlined and everyone is equal in every way. The principles of communism are quite ideal if you know what I mean, ideal being the operative word. The utopian society does not force everyone to be equal rather it allows everyone to be equal. Poverty, malnutrition, starvation, and unemployment are all eradicated. However once humans are put into the mix, again laziness and apathy

> take hold. A favorite Karl Marx quote of mine is, "I am not a Marxist." This illustrates that although he was a brilliant philosopher, he was not a true politician. He wrote of utopian societies, but knew they would never exist. Interestingly the word utopia means "no place" (from Greek ou "not" + topos "place") (http://www.etymonline.com/index.php?term=utopia) This being said I am not sure if humans will ever be responsible enough to respect the environment NO MATTER THE ECONOMIC IMPLICATIONS, however at the present it is clear that our forests, rainforests, beaches, and natural resources are being destroyed. Because information, know how, and billions of dollars of efforts to enlighten have not swayed the public, I believe it is time to restrict humans from portions of the environment. (student comment on online discussion board, November 13, 2006)

Similarly, the following student exhibited passion in her belief that cooperation among states was necessary to return the Chesapeake Bay to health:

> It's sad that so many people just think of their own state or even their own community as the only priority. The issue shouldn't be over "Should we spend money to help out another state?" That's just small thinking. The big idea is to see the world as one big ecosystem that humans must maintain and protect. I guess it just makes me mad to hear things like "Should we help Marylanders?" coming from politicians and even regular people. The answer is yes! because it's not about trying to make one state better than the other and putting blinders on to other problem. It's about overall ecosystem health. (student comment on online discussion board, April 3, 2006)

The student-to-student comments posted on the discussion boards further reflect a high level of engagement for many students, particularly where the cases were relevant to them. Students responded directly to their online peers 1,370 times in the 5 cases analyzed. This significant level of "student-student" interaction supports the conclusion that students established communities of learners. For example, one student made this energetic comment in response to another's beliefs about global warming:

> Wow! I really like your metaphor in the end and I want to say I agree completely with your entire passage. If we want to do anything about this growing problem, we should not just do something for a few years and then all of a sudden go back to our old ways, but instead make small changes that we can make permanent after time. Haste makes waste—or in this case, increased temperatures! As you said, we did not just all of a sudden have this technology that enhanced the greenhouse effect and *BOOM* cause this problem in one day. Instead we realized what was going on with global warming and it is not *entirely* too late to try and decide what we can do about it. Considering this problem was not made in a day, I am sure the solution will not be found and implemented in just one day either. It takes time. (student comment on online discussion board, January 15, 2006)

Many of the comments previously cited reflect the high level of interaction among students, again supporting a finding of engagement.

The survey responses also show the students' engagement. A full 61% of the students who responded to the survey found the course engaging. Moreover, 62% agreed the discussions were useful to their understanding of content, and 77% agreed the case content opened up avenues for discussion.

Evidence of Challenge

The very nature of case-based learning places demands on students, including: critical analysis ability, writing skills, reading and questioning skills, creative problem-solving skills, and the ability to deal with ill-structured problems. The online nature of the course also provides inherent challenges, in that the student must work independently, have strong time management skills, and be able to be his or her own advocate from time to time. Indeed, the online, case-based aspect of the environmental science course was purposefully designed to provide both challenge and engagement for the learner.

Strong evidence of challenge exists from the data. First, the numerous examples of learning and engagement described above offer evidence of challenge for many students. Second, several parents and school contacts sent e-mails to the Project administrators attesting to the challenge students experienced. One example is:

> Although their grades do not necessarily reflect it, they are both working very hard and learning a lot in this class. [My older son] is especially enjoying the opportunity to do something more meaningful and challenging and the effort he puts into this course is spilling over into his daily school work. He is a much more motivated student. Thank you for this opportunity. (parent e-mail communication, October 26, 2005)

Another example is:

> My son has worked harder for this course than any he has taken to date. Occasionally he gets frustrated with technical glitches that cause him to have to re-do work, etc., but, overall, he is finding the material extremely challenging and interesting. (parent e-mail communication, June 14, 2006)

Finally, the student survey results further support a finding of challenge, with 60% of responding students agreeing the course was challenging. However, 52% thought some of the work, specifically the note taking and reading questions, was mundane.

While the low survey response rates limit the conclusions we can make, these responses are supportive of challenge.

Weak Evidence of Learning, Engagement, and Challenge

Although most students demonstrated learning, with many also showing engagement and challenge, this cannot be said for all students. Of the 138 students enrolled in the course, 38 (27%) did not pass. Only 2 students reported in the survey that they did not feel like they learned anything new about environmental science. Additionally, the overall low passage rate on the AP examination challenges the conclusion that most students experienced enduring learning.

A number of students also posted comments that lacked the details suggestive of learning. These 192 responses were coded as “weak response” in that they demonstrated no evidence of learning or elaboration of ideas. For example, in response to the question “What do you know about invasive species from reading and studying the case?” one student replied “there are alot of endangered species I didn’t know about” (student comment on online discussion board, December 29, 2005). Another student responded to the question “What resolutions are possible?” in the open dumping case as follows: “None really because this is a complex problem and the answer is not easy” (student comment on online discussion board, March 23, 2007). Other students simply stated “I agree” in response to their classmates’ postings and failed to provide any evidence of independent thinking. These examples are representative of those students who did not appear to be fully engaged in the content or with their peers and who did not seem to have endeavored to fully analyze the cases presented. Although most students made demonstrably meaningful efforts to think as a scientist and show their understanding, this cannot be said of all students.

Discussion, Limitations, and Implications

As evidenced by the analysis of the student discussion boards, case resolutions, student grades, surveys, and e-mails, the Project did provide a viable learning alternative for a traditional AP environmental science course. Indeed, many of the students who participated in the Project's environmental science course experienced learning, engagement, and challenge. Specifically, the Project promoted inductive thinking and the use of problem-solving skills as it called upon students to interpret data, analyze case studies, and solve complex real-world science problems. Consequently, students practiced in a science discipline in much the same way that practitioners do. As such, the online, case-based environmental science course satisfied best practices for both gifted and science education.

Overall scores on the AP Environmental Sciences examination warrant further consideration. Again, only 30% of the students who took the AP exam earned a score of 3 or higher even though a far greater number of students passed the course. Clearly, colleges and universities regard participation and success in AP courses as indicators of academic success in high school (College Board, 2006b; Kyburg, Hertberg-Davis, & Callahan, 2007). Thus, a higher percentage of students passing the AP with a score of 3 or more would have buttressed the conclusion of these researchers that learning occurred.

It should also be noted that the researchers did not evaluate student grade and AP score outcomes for different instructors. Data reflecting such outcomes are no longer available due to loss of data. The inability to correlate course grades with AP examination scores and by instructor constitutes a limitation of the research design as such an analysis may have provided important information and supported additional conclusions about learning outcomes.

Nevertheless, these scores are notable as many of the students were in learning environments where AP courses are not regularly offered and resources and supports for AP courses are lacking. Some were middle school students. In addition, there is no way to know how these students would have performed on the AP examination if they had taken a traditional AP course, if the course incorporated AP test preparation, or how those students who did not take the AP exam would have performed.

More importantly, the intent of the Project was not to simply put an AP course online, but to provide a case-based alternative course designed to address advanced learners' needs. Thus, purposeful preparation for the AP exam was not a central feature of the course, and passing the AP exam did not alone serve as indicative of success. Rather, evidence independent of the AP exam, including the above-referenced results demonstrating learning, engagement, and challenge, supports the conclusions of success. The following comment made by a school contact reflects this sentiment:

> My student thoroughly enjoyed the course. Every time I spoke to her about it, she was enthusiastic. I was grateful she had the opportunity to take it. After the AP exam, I asked her how she felt she did. She said it was difficult because the course was case based and did not emphasize the types of questions that were on the AP exam. However, she was very pleased with the course. Although she received an A+ in the course, she only got a 2 on the AP exam. Her combined SAT scores were 1920, so I think she may have been able to do better on the AP exam if she was better prepared. However, doing well on the exam was not a primary concern of hers or mine so I am not writing this as a criticism, just as an observation. For the students in our school who took AP Environmental here, the average score was 2.8, with 71% scoring a 3 or better. (school administrator e-mail, June 18, 2006)

A successful learning experience is, therefore, more than an AP examination score. Engagement and challenge in an online case-based science course can lead to higher level thinking, further questioning, thinking like a scientist, and learning in general (Wilson et al., 1997/1998). Learning covers more than the retention of science concepts and problem-solving steps. It also includes the development of time management skills, self-advocacy, and awareness of how one learns best. The online case-based format proved to be a positive learning environment for many students, while other students found it an inappropriate fit.

Also warranting discussion is the acknowledgement that the course was designed with advanced students and students from poor and rural communities in mind. However, the Project ultimately was unable to confine the study to those students. Moreover, complete demographic data for the participants were not provided. Consequently, a complete examination of the impact of the Project on the intended subpopulations cannot be fully studied. This represents a limitation in the study design.

Notably, students who were independent learners with strong time management skills and were more active on the discussion boards had the most success with the course. This result is consistent with prior research (Wilson et al., 1997/1998). As one school contact stated, "This was our first experience with virtual learning in a high school setting. It confirmed our belief that it can work successfully when matched with independent learners" (school contact e-mail, June 2, 2006). One parent similarly commented that her daughter

> loves it and has learned a great deal. In particular, she has learned a great deal about being an independent learner and a more thoughtful student. I would guess that means, with this student at any rate, you have achieved half of your objectives! (parent e-mail, May 28, 2007)

Conversely, students with weaker time management skills struggled and/or eventually dropped the course. The following student comment reflects this assertion:

> My apologies for not responding sooner. I have come to the conclusion that a course that is self-scheduled and almost entirely self-motivated is not the most efficient way of learning for someone with my attention span.

> Evidently, the only thing that makes me do my work for school is knowing that I'll get in trouble if I don't, whereas for this all I will receive is some angry text. I haven't really been putting as much effort into this as I could and should have been (I'm referring to before these past few days when I haven't logged on at all) but I can't picture myself trying to keep this up until May. My relief at not having to do this will, admittedly, exceed my disappointment at myself for dropping the course. (student e-mail, October 25, 2005)

Another student who ultimately dropped the course acknowledged "I'm having a tough time with the class. I can do the work, but I find I am not putting my best. I have a difficult time managing this class with my other school classes" (student e-mail, January 26, 2007). This proved true with a number of students whose schedule changed second semester. There was an increase in dropouts at this time due to new class schedules, sports, and extracurricular activities. Some students managed the shift and appreciated the flexibility of online learning, others did not. This pattern of behavior and insight into the type of learner successful in an online environment may help in early identification or screening of students who might or might not be successful in this learning environment.

Further Research

As previously stated, the Project developers endeavored to address the problem of access to highly challenging science curricula for economically disadvantaged, rural, or otherwise underserved advanced learners by creating, implementing, and distributing an online case-based science course. These students were specifically targeted by the Project. Ultimately, however, the Project could not limit the course to these participants alone, and the demographic breakdown for each individual student could not be ascertained. To more fully understand the learning experiences of underserved, advanced students who were exposed to the type of curricula provided by the Project, more precise identification criteria and demographic data are needed.

Due to the difficulty some students had with time management, one instructor recommended that the Project "screen students for only the most capable and most highly motivated" (instructor e-mail, June 4, 2007). Additional research that could provide guidance to parents and educators in determining which student characteristics—such as independent learners or strong time managers—contribute to success in the type of alternative, advanced learning environment seen with the Project is recommended.

Educators should also pursue ways to ensure success for students who are not independent learners or who need more support and scaffolding. We found that students who had a stronger support system, such as adult support in physical proximity, were more likely to complete the course in good standing. External motivation seemed more important than expected for many students, and learning for the sake of learning did not affect all students equally. Pursuing motivating factors, particularly for those students from a lower socioeconomic background, is an area that needs further study. Similarly, pursuing research designed to better enable educators to predict which motivating factors are needed to help students who might need more support in order to achieve is urged.

Finally, an interesting impression derived from this study is that the instructors played little, if any, role in the overall success or failure of the students. That is, learning and engagement resulted principally from student-to-student interactions, and without significant instructor facilitation. This impression, while not systematically studied, differs from other research supporting the proposition that teacher characteristics often impact the success of students in a class (Wenglinsky, 2002; Wilson et al., 1997/1998). It is also distinguishable from the research on PBL and case-based learning that assumes students will "rely on the teacher to help guide the learning process" (Hmelo-Silver, 2004, p. 235; National Research Council, 2000). An interesting avenue for further research would be to explore more fully the role instructors play in an online case-based learning environment similar to the one seen in the Project. This study's failure to examine the role of instructors in the overall success or failure of participants reflects a limitation of the study.

We conclude with the recommendation that researchers continue to investigate alternative options for gifted and advanced secondary learners beyond traditional AP courses. This is particularly true for academically advanced students attending poor or rural schools where access to advanced course options and gifted programs are limited, students who cannot fit additional advanced courses into their school schedules, or homeschooled or homebound learners. Although we conclude that Project LOGgED On offered one such viable learning alternative, the continued development of a broad range of curricular options for advanced secondary students warrants additional attention.

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Appendix
Final Coding Scheme

Codes (# student responses)	Subcodes (# student responses)
Student Learning (4,839)	Thinking as a Scientist (1,418) Supported Opinion (260) Stated Opinion (883) Thinking as Scientist II (335) Higher Level Thinking (1,450) Logic (29) Combining Concepts (117) Bringing in Own Experiences (340) Making Connections to Other Content (39) Making Connections to Other Cases (33) Questioning (713) Higher Level Thinking II (179) Nature of Science (79) Learning Statements (434) Factual Content (1,458) Weak Response (192; not counted in total for Thinking as a Scientist)
Student Engagement (1,915)	Enthusiasm (215) Passion (168) Outreach (57) See Value in Content (99) Beyond the Course (6) Student-Student Interactions (1,370)