Examining the Student Impact Following an Online Professional Development Course for High School Biology Teachers

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ABSTRACT

Teacher professional development is usually designed with the ultimate goal of improving student learning through improvements in teacher knowledge and practices, yet relatively few studies have examined the impact on student knowledge as a result of their teachers having participated in professional development. In the current study, we aim to understand the relationship between a high-quality, online professional development program for high-school biology teachers and students' content knowledge of genetics and evolution. The professional development program is intended to enhance high-school biology teachers' subject content knowledge, pedagogical content knowledge, and use of digital resources. In addition, we explore the moderating influence of program duration on student impact. The study included 1,110 students of 32 teachers who completed the professional development course in the summer, and 2,238 students of 55 teachers in a control group. We found that students in the treatment condition had a stronger rate of growth across the year in genetics and evolution content knowledge compared to the control group. We also found that stronger impact occurred with the slightly shorter, more focused version of the course. With this paper, we hope to contribute to the understanding of important predictors of students' biology achievement, as well as to highlight the importance of professional support for high-school biology teachers.

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Introduction

The ultimate goal of most teacher professional development programs is to have an impact on student learning. Usually this goal is obtained indirectly by aiming to improve teachers' content knowledge of a particular subject, pedagogical content knowledge, or teaching practices. In theory, professional development is designed to influence their teaching practice, which in turn is assumed to have direct impact on student learning. However, researchers and evaluators should not assume a direct association between teachers' professional development and student outcomes.

It is critical to examine further the assumed direct association between professional development and student outcomes, since it is next to impossible to track every change in knowledge and behavior a teacher may exhibit following professional development. Impact of professional development may vary widely across teachers, depending upon contextual factors and on their previous teaching strategies and knowledge. The exact changes in teachers may also be difficult to measure, especially when time or resources do not allow for lengthy or multiple observations or assessments. Even when changes in teaching practice are found, it is impossible to conclude that they are the only changes that may have occurred that affect student outcomes. Teachers can implement ideas from the professional development in countless ways that may not be accurately measured by one or even several observations or assessments. Not even large-scale statistical models can account for all the variance in teaching practices (e.g., Wallace, 2009). Analyzing the direct association of professional development to student outcomes can take into account all of the measured and unmeasured changes to teacher knowledge or practice.

Variations in how professional development programs are run may also influence their impact on teachers and students (e.g., Desimone, Porter, Garet, Yoon, & Birman, 2002; Kanaya, Light, & McMillan Culp, 2005). For example, Kanaya et al. (2005) studied several variations of one professional development program and found that the total duration of the program affected how teachers were able to learn and implement the material. The authors also found that the amount of material covered and the workload, or intensity, during the time span of the professional development also influenced what teachers took away from the program. Thus, researchers should consider how variations within a professional development program affect the outcomes.

In the current study, we aim to understand the relationship between a high-quality, online professional development course for high-school biology teachers and their students' genetics and evolution content knowledge. In addition, we explore the moderating influence of course duration on this relationship. The course focused on learning content knowledge, inquiry and other teaching strategies, and the use of digital resources for teaching two challenging high-school biology topics: genetics and evolution. Two versions of the course were provided. One was a five-week course and the other a seven- to eight-week course. The two versions of the course were comparable in the pedagogical content they presented around genetics and evolution. The longer course had some additional pedagogical content for teaching general biology. Overall, the intensity of the courses was similar, but the duration of the course may have had an influence on how teachers were affected. Thus the research questions that guide this paper are:

1. Does teachers' participation in the course lead to an increase in students' knowledge of genetics and evolution?

2. Does the duration of the course influence the impact on student learning?

Literature Review

To answer our two research questions, we reviewed the literature on how professional development for teachers can affect students. We began with a general search of the impact that professional development can have on students across all content areas, then narrowed our search to look specifically at professional development programs in science. We also looked at studies that discuss the impact of online professional development programs, such as the course examined in this paper. Lastly, we reviewed aspects of professional development, such as duration, that may mediate the impact courses can have on teachers or students.

Models of Professional Development Impact

Researchers and educators hypothesize that changing teachers' pedagogical and content knowledge will lead to improved teaching, which in turn will lead to improved student outcomes (Banilower, Pasley, & Smith, 2001). Thus, professional development programs for teachers often aim to enhance teachers' content knowledge of a subject, pedagogical content knowledge, or instructional practices. Researchers have found evidence that effective professional development programs can successfully impact these areas for teachers (e.g., Garet, Porter, Desimone, Birman, & Yoon, 2001). Professional development programs that target teacher knowledge and practices have also been shown to impact student performance (e.g. Wallace, 2009).

The knowledge teachers need to affect student knowledge is complex and can be supported by professional development. Shulman's (1986, 1987) work on pedagogical content knowledge has identified two very distinct sets of knowledge: content knowledge and pedagogical content knowledge. Teachers must know the subject content of what they are teaching, as well as how to use and translate this knowledge to students via effective pedagogical strategies. Hill, Dean, and Goffney (2005) present an example in mathematics where they looked at the impact of teachers' specialized mathematical knowledge and the skills they used when teaching, and examined how these influenced students' learning trajectories. The authors found student achievement gains to be related to teacher knowledge in both first and third grade.

Research around professional development is needed within each content area to get an accurate picture of how it can impact student learning. The pathway to improving student knowledge through pedagogical content knowledge can vary on factors such as grade and subject area (Hill et al., 2005; Shulman, 1986) have also stated that this pathway is complex and unique for each subject area. The knowledge and pedagogical practices teachers use to impact students in each subject area are complex and unique. The level of sophistication required to capture the entire teaching and learning process is too great for most studies. This is why researchers often have looked directly at the impact professional development has had on student outcomes rather than attempting to create a model that includes all the potential mediating teacher knowledge and behaviors. Mediating teacher information can make student analyses more powerful, but is not necessary to analyze student impact following professional development.

Math and Reading Professional Development

There has been a good deal of research performed in mathematics and reading around professional development and its impact on teachers and students (e.g., Garet et al., 2010; Gersten et al., 2010). There are a few good examples of studies that directly examined the association between professional development and student outcomes. For example, Garet et al. (2010) performed a study of a mathematics professional development aimed at improving teachers' ability to teach positive rational number concepts effectively. The professional development included a three-day summer institute and a series of one-day follow-up seminars held during the school year, with in-school coaching following each seminar day. The researchers found that the program did not produce an impact on teacher knowledge, but did affect teachers' frequency in engaging students in activities that elicited student thinking. The authors additionally found a direct impact on students; students of teachers who participated in the professional development had significantly higher scores on a student achievement test.

Another mathematics professional development program that has shown impact on students is a teaching strategy called cognitively guided instruction (Villasenor & Kepnor, 1993; Carpenter, Ansell, Franke, Fennema, & Weisbeck, 1993). For example, Villasenor and Kepnor (1993) studied 12 first-grade teachers who participated in a 19-hour staff development workshop aimed at incorporating constructivist teaching into the teachers' curriculum through cognitively guided instruction. When compared to 12 control teachers, the experimental group taught arithmetic using more word-problem strategies and less time on worksheets that targeted specific skills. Classroom observations also revealed that experimental teachers focused more on the processes that students used in finding a solution rather than rote procedures to solving problems. Subsequently, students were tested after five months and those in the treatment classrooms outperformed the control group on a word-problem test (controlling for pre-tests) and successfully completed a higher number of number facts during interviews. The authors found that students of treatment teachers also used more advanced strategies when answering questions on number facts and when answering word problems.

Researchers studying professional development programs on reading also have performed similar analyses and have found similar effects. For example, Gersten et al. (2010) studied the impact of a teacher study-group program where the teachers met 16 times across the course of a year to work on improving their reading pedagogy for first-grade students. The authors found that treatment teachers scored higher in pedagogical content knowledge for reading and were observed to have stronger comprehension- and vocabulary-teaching practice. Students of treatment teachers showed significant gains on oral reading fluency. Gersten et al. (2010) did find relationships between teacher and student outcomes, as predicted, but more importantly, the authors also found a direct relationship between taking the professional development and student outcomes.

Borman, Dowling, and Schneck (2008) performed a multisite cluster randomized field trial of a widely used reading curriculum. In this study, treatment teachers implemented the curriculum, which included two-to-three days of training and periodic visits from coaches. The authors compared students in the treatment classrooms with a control group and found stronger gains on a standardized student aptitude test.

Science Professional Development

There has been less research performed in science around professional development and its impact on teachers and students. A few studies exist where researchers examined the association between professional development and student outcomes (e.g., Johnson & Fargo, 2010; Silverstein, Dubner, Glied, & Loike, 2009). The few that have been done have found that science professional development targeted at specific pedagogical content knowledge can have a direct impact on students. For example, Johnson and Fargo (2010) studied the impact of a two-year professional development on sixth- and seventh-grade teachers and students in one urban school district. The professional development program consisted of two weeks of training on pedagogy around earth science, with eight monthly follow-up sessions and teacher observations. The second year consisted of eight days of training with similar follow-up. Using observational data, treatment teachers were found to have improved their teaching strategies. In the second year of the study, students of treatment teachers had stronger gains in student achievement tests, based on state science assessments.

Silverstein et al. (2009) also studied the impact of a science professional development. The authors studied a program for high-school science teachers where teachers had trainings one day per week for 16 weeks over two summers. In the two years after teachers completed the program, students of the treatment teachers scored higher on state science exam scores than students of non-participating teachers. The authors performed surveys before and after the treatment and found some reported teaching differences. These teaching differences were used to help explain the observed impact on students, but did not nearly account for all of the change.

Online Professional Development

The studies discussed above have mainly had a face-to-face platform for delivering professional development. More recently, online professional development opportunities for teachers have become increasingly prevalent across all content areas. More studies are needed that focus on the relationship of online professional development for teaching pedagogical content knowledge to teacher and student outcomes.

Research about the effectiveness of professional development using an online platform is scarce and often presents contradictory results (Tallent-Runnels et al., 2006; Whitehouse, Breit, McCloskey, Ketelhut, & Dede, 2006; Zhao, Lei, Yan, Lai, & Tan, 2005). According to the few empirical studies available, online professional development has been less effective at changing teachers' classroom practices or improving student performance than for increasing teachers' specific content knowledge or changing pedagogical beliefs (e.g., Dominguez, Nichols, & Storandt, 2006; Doubler & Paget, 2006; Douglas, Russell, Kleiman, & Carey, 2009).

For example, Dominguez et al. (2006) studied two online science professional development courses for teachers. One course focused on teaching pedagogical content knowledge and reform-based teaching practices to help students learn fundamental algebra concepts in grades 3 through 5. The other course focused on geometry. The authors found that teachers had significant gains in beliefs around reform-based teaching. The authors did not find significant change in teaching practices or student achievement gains, however.

O'Dwyer et al. (2010) performed a more comprehensive study of online professional development that focused on English or mathematics in four different grades. The professional development contained theoretical information and pedagogical techniques that could be used in the classroom and consisted of 100 hours of online training over two years. The authors found that students whose teachers had participated in the online professional development program achieved larger gains on standardized measures across the academic year. Treatment students had stronger gains in math knowledge, reading comprehension, vocabulary knowledge, and writing.

Duration of Professional Development

Besides the online versus face-to-face platforms, researchers have discovered several other features of professional development that may mediate its effectiveness (e.g., Garet et al., 2001; Desimone et al., 2002). For example, Garet et al. (2001) performed a research project around the Eisenhower Professional Development Program that looked at how variations among professional development programs impacted teacher outcomes. The authors performed a nationwide study of 1,027 teachers across 358 districts who represented the national population of teachers. The teachers had each participated in at least one professional development program the previous year. The authors studied how six features of professional development were related to reported teacher outcomes. Three features were structural (reform type, duration, and collective participation) and three feature were core to the programs themselves (active learning, coherence, and content focus). Garet et al. (2001) found that all six features were related to increases in teachers' self-reported knowledge and skills. Each feature also was related to teachers' self-reported teaching practices over the next year. In describing this study, Desimone et al. (2002) noted that:

> "Activities with collective participation and longer duration were more likely to have active learning opportunities, coherence and a content focus, which in turn were related to how successful the experience was in increasing teacher-reported growth in knowledge and skills and changes in teaching practice" (p. 83).

Desimone et al. (2002) further tested whether factors such as duration had an impact on teacher outcomes from professional development. The authors performed a wide-scale study of 207 teachers in 30 schools, in 10 districts, across 5 states. Each teacher taught mathematics and science and had participated in at least one professional development course in the previous year. This study repeated the findings of Garet et al. (2001), except for duration. Duration of the professional developments was not related to teacher outcomes. These studies did not look at the effect of professional development variation on student outcomes.

Although Desimone et al. (2002) did not find a relationship of duration to teacher outcomes, several other studies have found that duration can affect the degree of teacher change (e.g., Furtak, Seidel, Iverson, & Briggs, 2009; Weiss, Montgomery, Ridgway, & Bond, 1998; Kanaya et al., 2005; Garet et al., 2001). Notable variations within a professional development program, such as duration, must be considered when analyzing the impact of the program on teachers and on students.

Methods

Participants

The participants were 3,448 students of 87 teachers of high-school biology in New York state. The current study included 1,110 students of 32 teachers in the treatment group who completed the professional development course in the summer, and 2,238 students of 55 teachers in a control group. The unequal group size was due to attrition. Teachers (and subsequently their students) who dropped out did not differ significantly on demographic or pre-course measures from those who persisted. The students' grade level and condition are displayed in Table 1. Of the 632 treatment students, 329 students had teachers who took the longer version of the course and 303 students had teachers who took the shorter version.

Table 1. Grade level and condition of all participating students

	Control group	Treatment group	Total
Grade 9	1137	448	1585
Grade 10	1201	662	1863
Total	2238	1110	3448

Students attended 74 different schools across various districts in New York State. These districts are classified by the New York State Education Department into need/resource capacity categories[1] as follows: 22% attended New York City public schools; 6.1% attended large city districts; 11.5% attended other, smaller school districts classified as "high-need urban-suburban;" 9.4% attended districts classified as "high-need rural;" 36.6% attended districts classified as having "average need;" and 14.4% attended districts classified as having "low need." Schools' proportion of students who qualified for free or reduced lunch ranged from 27% to 94 % (Mean = 36.1, SD = 26.8) and proportion of English-language learners in the schools ranged from 0 to 29 percent (Mean = 2.6, SD = 4.5). The student-teacher ratios of the schools ranged from 2.8 to 24.9 (Mean = 13.7, SD = 2.7). Of the 74 schools in which study participants were enrolled, 48 served predominantly white student bodies (>50% white), 8 served predominantly African-American student bodies (>50%), 7 served predominantly Hispanic student bodies (>50%), 9

[1] The New York State Education Department classifies school districts not only according to their wealth or fiscal capacity, but also by a measure called the Need/Resource Capacity Index (N/RC) that takes into account their degree of pupil needs, which is used to categorize school districts into similar groups based on indicators of relative district wealth, population density, and some important characteristics of resident students' special needs. NYSED has defined six need/resource categories: New York City; the Big Four City School Districts (Buffalo, Rochester, Syracuse, and Yonkers); high-need urban/suburban districts; high-need rural districts; average-need districts; and low-need districts.

served racially diverse student bodies, and 2 did not have student racial information available. Further individual demographic information was not available.

Intervention

The intervention at the core of the study is an online course for teachers of high-school biology. In the course, participants explore the "big ideas" of the hard-to-teach topics of genetics and evolution through exploration of online digital resources and reflection on a range of teaching strategies. The course was created by WGBH Teachers' Domain (www.teachersdomain.org), an online library of free digital resources and accompanying professional development materials. The multimedia collections of science resources in Teachers' Domain and its professional development courses are based on public television materials, such as the highly acclaimed *Nova* television series. Development over the last ten years has been supported in part by grants from the National Science Foundation. The course is distributed by PBS TeacherLine (www.pbsteacherline.org), a provider of online professional development courses for educators that is funded in part by the U.S. Department of Education. For the study, the course was administered by PBS TeacherLine NY and facilitated by experienced facilitators trained by PBS TeacherLine who were also science educators.

The course includes sessions focused on teaching genetics and evolution using inquiry-based approaches and digital resources. It is organized according to the "5 E's" learning cycle: engage, explore, explain, elaborate, and evaluate (Bybee, et al., 2006). Sessions contain readings, video clips, written notebook reflections, discussion boards, and one-to-several session assignments. The sessions model the kind of pedagogy that participants can use with their students. There are two versions of the course in this study:

(1) *Teaching High School Biology* ("long version"): the 8-session, 8-week *Teaching High School Biology* course focuses on three elements—content knowledge, inquiry as well as other teaching strategies, and the use of digital media in teaching and learning—through teaching genetics and evolution.

(2) *Teaching Genetics and Evolution* ("short version")*:* the second, shorter version of the course is, in essence, sessions 3 through 6 of the *Teaching High School Biology* course and takes place over 5 weeks. These sessions focus exclusively on teaching genetics and evolution.

Data sources

The following were completed by all students at the beginning and end of the school year:

Knowledge of Genetics and Evolution. We administered a standards-based assessment at the beginning and end of the academic year. We created this assessment from old versions of the New York Living Environment Regents Exam. Public school students in New York State typically take this standardized biology test in grade 9 or 10. The New York State Education Department administers the exam three times a year. Released tests from 2003 to 2009 are available on the New York State Education Department website, along with scoring guidelines and a table of specifications that labels each item with the related core curriculum standard. Two researchers, both former biology teachers, reviewed six years' worth of Living Environment Regents exams and identified genetics and evolution items related to the relevant New York State standards. They considered each item's topic and level of difficulty so that the final student assessment would contain items that varied in content and difficulty. The resulting 20-item assessment includes 4 short-response items and 16 multiple-choice items. A biologist on the advisory board reviewed the final assessment before piloting, in order to ensure accuracy of the items. Care was taken to make sure students could complete the entire assessment within one class period, in order to limit the burden to teachers and students participating in the study.

Test of Science-Related Attitudes. At the same time points, students also completed the Test of Science Related Attitudes (TOSRA), which measures student attitudes towards science. The original TOSRA is a 70-item questionnaire that contains seven 10-item subscales measuring various attitudes students may have towards science (Fraser, 1981). Mountz (2006) used a modified version, with two 35-item questionnaires used as a pre-test and a post-test. The 10 items in each subscale were evenly divided between the two shorter versions and the positively and negatively phrased items were balanced. In the current study, because we wanted to analyze students' attitudes at the beginning and end of the school year, we used Mountz's modified questionnaires. We used six of the subscales, the seventh being irrelevant for the study, leaving 30-item pre- and post-assessments.

Data Analysis and Limitations

For the current paper, analyses are preliminary. We also are exploring the impact that attrition and missing data had on the following results. In addition, we will use hierarchical linear modeling to analyze the impact on students of teachers taking the course. Hierarchical linear modeling will be used to create a nested design, since students are nested within classrooms. The model will also include covariates at the school and teacher levels. The current analyses are the repeated measures analyses of covariance analyzing changes in student knowledge using only student-level covariates.

Preliminary Findings

Our first research question addresses teachers' participation in the professional development course as it relates to students' performance on the Knowledge of Genetics and Evolution assessments:

Does teachers' participation in the course lead to an increase in students' knowledge of genetics and evolution?
Students of teachers who took the course had larger gains in genetics and evolution knowledge compared to the control group. We analyzed students' growth from their pre-test to post-test in the treatment and control groups. To control for any bias from students' science-related attitudes, we controlled for their TOSRA scores. We also controlled for students' grade level, since the sample consisted of both ninth- and tenth-grade students.

Consistent with our expectations, the RMANCOVA revealed that all students improved over the course of the year, $F(1, 2860) = 7.2$, $p < .01$. When looking at growth, we also found a significant time X group interaction, $F(1, 2860) = 13.5$, $p < .001$, with the treatment group displaying a larger increase in content knowledge across the year.

Our second research question explored whether the two variations of the course, mainly varying in duration (long course versus short course), showed differing impacts on students:

Does the duration of the course influence the impact on student learning?

We found that teachers who took the short version of the course had students with larger gains in knowledge compared to students of teachers who took the long version. Both treatment groups showed larger gains than the control group (see Table 2). We use RMANCOVA to measure whether the gains in student knowledge growth were different across condition and course duration, controlling for the same covariates.

We found that all students improved across the school year in genetics and evolution knowledge, $F(1,2859) = 7.6$, $p < .001$. A marginally significant difference between groups (long course, short course, and control) was also found, $F(2,2859) = 2.7$, $p = .066$. Most importantly, we again found a significant time X treatment interaction, $F(2,2859) = 8.9$, $p < .001$, with both treatment conditions showing a larger increase compared to the control group. When isolating just the short-and long-course treatment conditions, the short-course–treatment students showed a larger increase in learning across the school year, $F(1,883) = 4.4$, $p < .05$ and higher scores overall, $F(1,883) = 5.4$, $p < .05$.

Table 2. Means and standard deviations for students' genetics and evolution pre- and post-tests separated by treatment group.

	Pre-test	Post-test
Control Group	8.21 (SD = 3.02)	11.03 (SD = 4.22)
Treatment Group	8.06 (SD = 3.26)	11.40 (SD = 4.06)
-Short Version	8.23 (SD = 3.26)	11.83 (SD = 3.29)
-Long Version	7.93 (SD = 3.26)	11.04 (SD = 4.14)

Discussion

The results in this paper are preliminary, but this study has important implications for professional development activity in science education. Results indicate that effective, high-quality professional development for high-school biology teachers based around strong pedagogical practices and digital media can lead to improvements in students' content knowledge in genetics and evolution. This study helps to build support for creating and implementing similar professional development programs that may help biology teachers foster student learning in other science content areas, as well as other grades.

This study shows that an online, science-focused professional development can have a significant impact on students. Studies such as Gersten et al. (2010) and Borman et al. (2008) have shown similar association with professional development programs around reading and language arts. Similarly, Garet et al. (2010) and Villasenor and Kepnor (1993) showed similar findings with mathematics-based professional development programs. Less research has been done around science professional development, but this study lends supports to those that have found similar positive impact on students, such as Johnson and Fargo (2010) and Silverstein et al. (2009).

This study also demonstrates that an online medium can be effective for professional development. This finding is important, since previous literature around online professional development has had mixed results. For example, Dominguez et al. (2009) studied an online science-based professional development program and found an impact on teacher knowledge, but did not find a significant gain in students' knowledge. Outside of science, however, O'Dwyer et al. (2010) studied an online, 100-hour, two-year professional development program around mathematics and reading, and found the program had a significant impact on student knowledge. Our study has shown that online professional development in science can also lead to an increase in student knowledge.

Results of this study also show that longer professional development programs are not always better, and a stronger impact may occur with slightly shorter, more focused courses. However, the duration of these two courses differed by only a couple of weeks, whereas studies such as Kanaya et al. (2005) looked at professional development programs whose duration varied by months. The intensity of the two versions of this course was also comparable, whereas Kanaya et al. (2005) found the strongest effects when duration and intensity were greater. This study shows that even minor variations of professional development programs should be accounted for when analyzing impact if the programs are going to be implemented.

This study also compliments our previous analyses around these Teachers' Domain-designed courses. We have previously demonstrated that these courses can impact teacher pedagogical content knowledge, genetics and evolution content knowledge, and knowledge of using digital resources (Goldenberg & Strother, 2010). The current study and that study together show that online science professional development can have a direct association with teacher and student knowledge. We later plan to analyze the data using a mediated model where teacher knowledge mediates the impact of the professional development on student learning, as suggested by researchers such as Garet et al. (2010).

We have also performed case studies looking at how teachers implement what they learned from the courses. We performed teacher and student interviews, site visits and observations, and artifact collection for eight treatment teachers to further understand in-classroom teacher practice that might be mediating the student impact seen in the current study. The case studies are currently undergoing analyses and should further inform how these courses can benefit teachers and classrooms.

One limitation of the study lies with the two versions of the course. The courses were not identical in content, so conclusions about duration must be viewed tentatively. Further studies regarding the duration of online professional development courses and the ways in which it may affect teachers and students are still needed. Another limitation in the current study is that it does not include variables at the teacher level. This issue is being addressed with the case studies we have performed. It will also be addressed when our fully mediated analyses are run using hierarchical linear modeling. Teacher and school level covariates will be included in these analyses.

Conclusions and Implications

This study showed that an online science-based professional development course can be successful for helping students learn biology content if it focuses their teachers on learning pedagogical content knowledge, subject content knowledge, and knowledge about using digital media. Research around the outcomes of professional development trainings has historically produce mixed results and small, if any, effects at the student level. Getting teachers to shift their pedagogical strategies can be difficult, and showing student impact from trainings is even more unlikely. The current study shows that high-quality professional development in science through an online format can, in fact, positively impact high-school biology students' content knowledge.

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