Improving Community College Student Learning Outcomes in Biology

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Abstract

Improving student learning outcomes in basic science courses through the introduction of innovative teaching strategies is a challenging goal. Keller's Personalized System of Instruction (the Keller method) is an instructional method that is grounded in theory and that focuses on improving learning outcomes. The purpose of this study was to determine if implementation of the Keller method would be beneficial for community college biology students, leading to improved learning outcomes and neutralizing learning disparities associated with student gender and race/ethnicity.

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Introduction

Improving student learning outcomes in basic science courses through the introduction of innovative teaching strategies is a challenging goal. For example, many instructors endeavor to tailor teaching strategies to accommodate students' learning style preferences. However, Pashler, McDaniel, Rohrer and Bjork (2008) reviewed a number of these efforts; their review provides a compelling argument that tailoring instruction methods to students' learning preferences does not consistently produce optimal outcomes. Although variants in teaching strategies are not always successful, one instructional method that has demonstrated the potential to help students achieve successful learning outcomes in a variety of academic disciplines is Keller's Personalized System of Instruction, commonly known as Keller's PSI or simply the Keller method (Buzhardt & Semb, 2002; Eyre, 2007; Keller, 1968; Kulik, Carmichael & Kulik, 1974; Price, 1999).

The Keller method, grounded in personalized instruction, mastery learning and reinforcement theory, was developed in an effort to overcome some of the limitations of the traditional lecture format (Keller, 1968; Kulik et al., 1974; Sherman, 1992). Keller's method was developed in the 1960's concurrently with Bloom's Mastery of Learning and the two approaches share many commonalities, yet they differ. With Bloom's mastery learning, information is generally provided through classroom instruction and students progress through the semester at a pace established by the instructor; with the Keller method information is provided through written materials, the classroom session is used primarily for motivation, and students determine their individual rates of progress through the materials (Kulik, Kulik & Bangert-Drowns, 1990). Keller's unique approach within the realm of master learning differs from the traditional lecture format. Traditional lecture courses often proceed at a fixed pace; this approach does not accommodate diverse learning styles, student's individual learning paces, or levels of student academic preparedness. Furthermore, once a topic in a course has been covered and learning assessments on the topic have been completed, those students who have not achieved adequate learning outcomes may not be remediated. In essence, the student must master course content at a fixed pace or risk being "left behind".

The Keller method differs from the traditional course format (Keller, 1968; Kulik et al., 1974; Sherman, 1992). To implement the Keller method, courses are broken into discrete, manageable learning modules with specific learning objectives identified for each module. Comprehensive written learning materials are prepared for each module and made available to students. Classroom sessions are used primarily for motivation rather than instruction; attendance is optional. Students are allowed to test and re-test on learning modules until competency is achieved on each module. This allows students to proceed at their own pace based upon their unique learning styles and capacities for learning. Each time that students complete an exam on a learning module, they are promptly informed of their performance and they receive immediate feedback on those items for which the students did not demonstrate competency.

Through the testing, remediation and re-testing aspect of the Keller method, students who learn at a slower pace or who have inadequate academic backgrounds are provided the opportunity to catch up with those students who have stronger backgrounds or who learn at a more rapid pace. This tends to create an equalizing effect for students. Sherman (1992) notes that students in Keller method courses tend to score about a letter grade higher on comprehensive final exams than those in conventional courses, demonstrating increased competence. Furthermore, studies have revealed that those students who might initially be described as underprepared in baseline knowledge or aptitude tend to benefit the most through increased learning gains in courses based upon the Keller method (Caldwell et al., 1978; Ironsmith & Eppler, 2007; Kulik et al., 1990).

Science courses designed upon the Keller method have been successfully implemented in university undergraduate and post-baccalaureate programs (Cracolice & Roth, 1996; Fike, McCall, Raehl, Smith & Lockman, 2009; Lockman, Gaasch, Borges, Ehlo & Smith, 2008; Pelayo-Alvarez, Albert-Ros, Gil-Latorre & Gutierrez-Sigler, 2000). In a meta-analysis by Kulik et al. (1974) of 15 studies of the Keller method versus control groups, the Keller method yielded significantly higher student performance outcomes in 11 of the studies and no significant difference from controls in the other 4 studies. Applications of this method with non-traditional biology students in the community college have not been reported in the literature. Accordingly, this study was initiated to determine if an application of the Keller method would produce desired learning outcomes for anatomy & physiology students within the Biology discipline in the community college. Given that community college students generally are less academically prepared and have lower baccalaureate completion rates than university students, this study targeted an unexplored subset of college students who may be deemed at risk.

This study used quantitative methods in an effort to confirm theory depicted graphically in Figure 1 that the Keller method creates a learning environment where community college biology students are able to achieve improved learning outcomes regardless of their initial levels of preparedness. If the Keller method is applicable to non-traditional community college students, then courses taught with the method will help to neutralize learning disparities attributed to initial levels of academic preparedness associated with student gender and race/ethnicity. In particular, males and minorities should achieve parity with females and non-minorities in learning outcomes. Furthermore, a qualitative review of the benefits and limitations of the Keller method will be provided by instructors within the community college.

Methods

Course Design/Development

Anatomy & physiology (A&P) courses were developed for use within a community college setting. The courses were designed using the Keller method framework. Course content was divided into more than 20 discrete learning modules. For each module, course instructors developed learning objectives and written/illustrated content materials. Course materials included a syllabus, descriptions of learning objectives, anatomical diagrams with labeled components, classification of systems, lists/descriptions of anatomical terms and locations, and ancillary materials to assist students in their learning endeavors; in essence, instructional materials were compiled into an e-portfolio. The learning materials were posted within a WebCT online courseware system. While the curriculum was equivalent to that of a traditional course, the content was delivered via the courseware system. Exams for each learning module were developed within WebCT. An extensive test bank was developed so that when students re-tested on a module, random selection of questions assured that students received a unique set of questions on each exam attempt. One characteristic of the course development effort was the relatively heavy time requirement preceding the course for faculty to collectively develop instructional materials and a large text bank, and to appropriately incorporate all materials into the electronic courseware system.

Module exams, developed by the instructors to assess student's knowledge, were comprised of open-entry questions, with students being required to correctly identify and spell anatomical terms. This approach minimized the likelihood of a student guessing the correct answer. The exams were administered in a proctored environment to assure academic integrity of the testing process. Given the focus of this introductory course, the exam questions targeted lower-order cognitive skills. The exams were designed to give immediate feedback/remediation when incorrect answers were submitted. Students were allowed to repeatedly remediate and re-test on learning modules in an effort to demonstrate improved mastery of material. Exams were comprised of randomly selected questions; when student re-tested on a module they were not presented with the same questions as the prior test. Since repeated testing was allowed, the course design differed substantially from courses based upon one-shot, "high stakes" testing.

Setting

Two instructors taught a total of six sections of the A&P courses during the fall and spring semesters of the 2008-2009 academic year. Each section was limited to a maximum enrollment of 28 students. The courses were offered at a public, urban, commuter-based community college in Texas with annual enrollment of about 10,000 students. The community college has received federal designation as a Hispanic Serving Institution (HSI).

Participants

For this study, the sample consisted of a total of 168 students in the A&P courses. The students were primarily female (88%). Caucasians comprised 62% of the sample; 26% were Hispanic and 7% were Black. Students age in years varied from 17 to 49, with mean age of 23.8 ± 6.1 (mean ± SD). Informal polling suggested that the majority of students were taking the A&P course to fulfill requirements for healthcare degree programs. There were no science prerequisites for enrolling in the introductory course.

Data Collection

Scores (percent correct) on each learning exam attempt by each student were collected in WebCT. A total of 7484 module exam attempts were initiated by students on a total of 25 learning modules during the two semesters. The learning outcomes data were subsequently transferred to SPSS and merged with student demographics data for analyses. The final dataset consisted of a record for each student's efforts on each learning module within a course. The data include the student's first attempt score (baseline) on each module, the student's best score on each module, the mean time per exam attempt on each module (a possible indicator of preparedness) and the number of exam attempts on each module, as well as demographics data such as age, gender and race/ethnicity.

To assure quality, the data were reviewed and cleaned, thereby correcting any erroneous data. Personal identifiers were removed to assure confidentiality. Prior to data collection, the study was approved by the Institutional Review Board.

Data Analysis

To confirm that the Keller method creates a learning environment where community college biology students are able to achieve improved learning outcomes regardless of their initial levels of preparedness, a path analysis was conducted using Amos 17 structural equation modeling software. Student t tests were used to test for differences by gender and race/ethnicity for baseline scores, final (best) scores, number of exam attempts and mean time for exam attempts per module. Two-way analysis of variance was used to test for an interaction effect of gender and race/ethnicity on final scores. Additionally, a qualitative review of the benefits and limitations of implementing the Keller method in A&P courses in the community college was provided. For all quantitative analyses, the level of significance was set at .05.

Results

Figure 1 provides a path analysis for A&P student learning outcomes. To facilitate interpretation of the model, unstandardized path coefficients are provided. The model depicted in Figure 1 is comprised of 1801 student-module records. Given 168 student participants, students completed a mean of 10.7 modules per semester. The null hypothesis for the model represented in Figure 1 is that the model implied covariance matrix is equivalent to the estimated population covariance matrix. The test statistic is Chi square = 7.3, df = 4, p = .12. Other goodness-of-fit statistics (CFI = .996, RMSEA = .021) reflect an acceptable model (Violato & Hecker, 2007).

The exogenous variable Gender is coded 1 for male and 0 for female. The exogenous variable Race is coded 1 for Caucasian and 0 for non-Caucasian. All path coefficients are statistically significant with a $p < .001$ for all paths except for the path from Race to First Attempt Score for which $p = .017$.

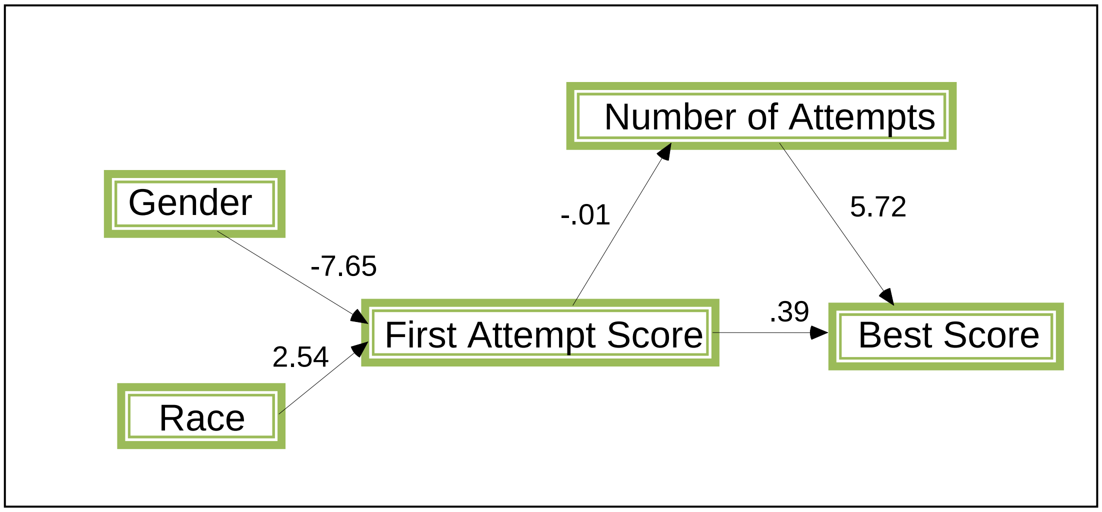

Figure 1. Learning Model Path Analysis with Unstandardized Path Coefficients

First Attempt Score is the student's baseline score on each learning module. Best Score is the student's best (e.g., final) score on each learning module. The mediating variable Number of Attempts represents the count of attempts by each student on each learning module. As depicted in Figure 1, males average about 7.65 points lower than females on First Attempt Scores and Caucasian average about 2.54 points higher than non-Caucasians. The unstandardized path coefficient for First Attempt Score to Best Score suggests that for each additional first attempt point, the student will average .39 additional points on the best score for the learning module. The path coefficient of -.01 for First Attempt Score to Number of Attempts reveals that student's with higher first attempt scores will make fewer attempts than those with lower First Attempts Scores. However, for each additional attempt on a learning module, a student can expect to increase the Best Score by about 5.72 points.

Table 1. Differences in Module Exam Outcomes by Gender and Race/Ethnicity

(Mean±SD)

Variable	Male	Female	p*	Caucasian	Non-Caucasian	p*
First Attempt Score	23.4±17.6	31.2±22.5	<.001	31.4±22.3	28.6±21.6	.010
Final Score	71.7±24.1	76.3±22.7	.007	76.0±23.1	75.6±22.4	.749
Gain Score	48.3±25.8	45.1±26.5	.105	44.6±27.1	47.0±25.3	.062

Number of Attempts	4.23±2.15	4.02±1.92	.154	3.98±1.96	4.15±1.92	.062

* Student's t

Table 1 depicts differences by gender and race/ethnicity in first attempt scores, final scores, gain scores, and number of attempts per learning module. A key finding from Table 1 is that although minorities underperformed at baseline, they effectively closed the gap in learning outcomes and achieved final scores roughly equivalent to those earned by Caucasians. While males in this study made positive learning gains, the gains were not sufficient to produce final scores equivalent to those earned by females.

A two-way analysis of variance was used to determine if the interaction of gender and race/ethnicity was associated with final scores. The interaction was significant ($p = .042$). Caucasian males had final scores of 69.1 ± 21.6 (mean ± SD) while non-Caucasian males had final scores of 75.0 ± 26.7. Caucasian females had final scores of 76.8 ± 23.1 while non-Caucasian females had final scores of 75.7 ± 21.8.

Discussion

Quantitative Assessment of Learning Outcomes

A review of the model represented in Figure 1 suggests that males and minorities demonstrate a lower level of knowledge at baseline. Since baseline knowledge is a positive predictor of final scores on learning modules, this implies that final learning outcomes for males and minorities may be lower than those of females and non-minorities. However, the Keller method provides the opportunity for those who are initially underprepared to reduce learning outcome disparities. Through more work (e.g., an increase in Number of Attempts), those who are underprepared can improve their final learning outcomes. This is one of the key attributes of the Keller method. A further benefit of the Keller method is that students can progress at a self-paced rate, and the testing environment is "low stakes". Based upon this study of nontraditional, community college biology students, the model represented in Figure 1 is consistent with research findings of other student populations that have shown that the Keller method provides the best benefit to those who are less prepared initially (Caldwell et al., 1978; Ironsmith & Eppler, 2007). In essence, the Keller method allows the underprepared students to "catch up".

Although the Keller method provides an environment where underprepared students are able to close the gap in learning outcomes, the results from this study are mixed. An encouraging finding was that non-Caucasians were able to achieve final learning outcomes that were equivalent to those of Caucasians. Thus, the instructional approach allowed non-Caucasians to achieve parity with Caucasians. However, males were not able to close the gap with females as measured by final learning outcomes. Further analysis of the interaction of gender and race/ethnicity revealed that Caucasian males underperformed relative to non-Caucasian males and all females. The reasons for this outcome are unknown. The findings suggest that application of the Keller method within A&P biology classes in the community college may be particularly beneficial in dealing with race/ethnicity learning outcome disparities, but it may not sufficiently address some of the challenges confronting Caucasian male students. Further study is warranted to explore reasons why Caucasian males did not achieve final learning outcomes similar to others.

With respect to quantitative analysis, this study confirmed theory that the Keller method yields a learning environment where community college biology students are able to achieve improved learning outcomes. All student groups achieved mean learning gains of at least 40% over baseline (Table 1) and multiple module exam attempts produced mean increases of 6% per attempt in final scores (Figure 1). With the Keller method applied to A&P courses in the community college, non-Caucasians students were able to close the gap in final learning outcomes. Application of the Keller method in biology courses within the community college should be considered in settings where there are race/ethnicity disparities in learning achievement.

Instructors' Perceptions of Benefits/Limitations of the Keller Method

Community colleges have an "open door" admission policy that ensures that academic programs are available to anyone who can benefit from a college education. Because of the "open door" policy, some students may be less prepared than traditional university students for the rigors of college-level science courses. There is a need for interventions to help community college students achieve successful learning outcomes in science courses. From the instructors' perspectives, assessing the merits of the Keller method as a possible intervention was clearly warranted.

The students who participated in the study were unaware that the A&P sections would be grounded in the Keller method prior to enrollment in the course. Although students self-selected the course sections in which they enrolled, they self-selected based upon criteria other than the method of instruction. So, the students in the Keller method sections did not appear to differ from their fellow students who enrolled in course sections which used traditional instructional formats.

The Keller method provided students with academic potential, but lacking adequate science background, an opportunity and encouragement to master course objectives. The self-paced structure and repeated testing opportunities led to a dramatic decrease in testing anxiety and an increase in content mastery. Immediate feedback and remediation improved recall of the material. Many students positively commented that this method, "bettered my study habits", and enabled "more knowledge retention" with "higher grades and better understanding [of the material]." Another student replied, "I like it. More classes should use this method." An unforeseen advantage of the module format for lecture was that students excelled in their identification and spelling skills on lab practical exams. In general, the students responded favorably to the instructional method and asserted that it promoted positive learning behaviors and outcomes.

The obvious benefits of the Keller Method were not without some challenges. An unfortunate result of the self-paced structure for students at this academic level was a propensity towards procrastination and a tendency to study tests instead of the instructional materials such as texts. Although the tendency to study tests was not encouraged by the instructors, it served as an alternative process for learning. Regardless of a student's approach to learning, student learning was assessed via the randomly-selected exam questions; learning was measured through a consistent process for all students. The module assessment process was challenging for students. Students remarked that they must *know* the answer on exams with this implementation of the Keller method, whereas a multiple choice format allows for higher probabilities of guessing correctly. Other major concerns were the issues of students' time constraints to repeat test attempts due to work, family, school/studies and the availability of a proctored computer lab. Some students repeated a module exam as many as 12 times in an attempt to improve their grade. The students then fell behind in their progress through the course content. Key problems for some of the students enrolled in the Keller method A&P sections were procrastination and poor time management.

Modifications were made to the Keller method courses to compensate for some of the challenges faced. Although initially students were allowed unlimited testing attempts, module assessments subsequently were restricted to five times per module in an effort to assure mastery of the material within the 16 week college semester. Also, the window of time allowed for a student to achieve competency on any particular module was limited, generally to two or three weeks per module. Although these two changes (limited number of exam attempts and time window) varied from the original Keller method, the impetus of the time restriction pushed students forward and prevented them from lagging behind.

Development and implementation of the Keller method A&P courses also presented unique challenges for the instructors. The courses needed to be fully developed prior to start of the courses, so considerable "up front" work was required. Since students were allowed repeated testing on modules, a large test bank of questions needed to be developed. Course logistics, such as establishing proctored, computer-based testing labs, also created challenges. In general, course development required more time and effort prior to course start than would be required with a traditional course. Once developed, the level of effort for teaching subsequent semesters became more manageable.

Summarizing the events of two semesters, initial implementation of the Keller method required some modifications to fully benefit the academically disadvantaged student. Based on personal experience of the instructors teaching by traditional methods, Keller's method tended to improve learning outcomes such as final student grades. The repetition and remediation provided students with essential tools and skills to further their academic and personal goals.

Limitations of the Study

Student demographic data were self-reported; the data could not be validated. Although the path analysis for this study confirmed that the Keller method provided an environment where learning outcome disparities could be reduced or eliminated, the study was not a controlled experiment so causality cannot be established. Care should be taken when generalizing the findings of this study to student populations that differ substantially from the student sample in this study.

Conclusion

The focus of this study was on improving learning outcomes for at-risk community college students. This study demonstrated that application of the Keller method within the community college was associated with improved learning outcomes for traditionally underserved minority students in a biology course. This is the first known study to demonstrate the impact of the Keller method on this unique student population. Minorities were able to close the gaps in learning achievement within the A&P course, thereby reaching parity with non-minorities. However, Caucasian males did not perform as well as others. Furthermore, students encountered procrastination and time management problems. Regardless of the challenges associated with implementation of the Keller method, findings from this study suggest that the Keller method provides measureable benefits and should be considered for use in community college settings where there are race/ethnicity disparities in learning achievement.

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