The Effects of an Interdisciplinary Program on Secondary Art Students Participating in an Interdisciplinary Chemistry-Art Program and in an Art Only Program

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Abstract

The purpose of this study was to determine the effects of an interdisciplinary program on the secondary level. The sample consisted of 17 students enrolled in a high school advanced photography class. The students in the sample varied in their chemistry background. The sample was randomly assigned to experimental and control groups. The experimental group had seven students and the control group consisted of ten students. The students in the experimental group participated in three days of intensive hands on chemistry instruction relevant to a photography project based on Van Dyke Brown Process. The control group did not participate in the chemistry instruction. After the instruction, both experimental and control groups were assigned a photography project. Data were collected using a rubric to quantitatively score the performance on the photography project. The rubric consisted of several subscales. Data were then analyzed using t-test for independent means. The results indicated a significant difference between the experimental and control group on their performance. The experimental group outperformed the control group in the overall scores, and on the measures of concepts taught and craftsmanship. The findings of the study suggest that secondary school students could benefit from and interdisciplinary program.

Review of the Literature

Interdisciplinary teaching is not a new concept, but instead one that was first established by Dewey and Parker in the 1890's progressive movement as a vital part of effective pedagogy (Hinde, 2005). Over the years, courses of instruction on all levels have become narrowed in focus and specialization. Unfortunately, the pace that information is added on a daily basis as prompted educators to return to the ideas of Dewey and re-learn the value of shared disciplines as they seek to find ways to help students connect with the fundamentals and make application to their world.

In a recent edition of the National Science Teacher Association Reports, the articles presented showed a host of examples on both the secondary and post-graduate level of interdisciplinary courses that tie in fundamental science to practical environmental studies. The lead article also illustrates the importance of co-teaching between a biology teacher and an education teacher in the training of pre-service science teachers ("Co-teaching to cover pedagogy, content," 2009).

To better understand what is meant by interdisciplinary teaching, this review covers four primary topics of relevance to this thesis. First, the question of what is meant by interdisciplinary teaching is reviewed. Second, the "need to know" principle is examined. Third, a review of the benefits of teaching with other faculty is presented and finally, a review of content specific examples that link science and art instruction together.

In searching the literature it was found that there are many more examples of interdisciplinary teaching on the post-graduate level then at the secondary level. Examples do exist however, and there appears to be an increasing awareness of the importance of this teaching method on the secondary level. Also encouraging is the examples of using interdisciplinary teaching at the primary level. It appears that in many ways, there is a need to broaden the scope of our content so as to not lose relevance. In many ways, teachers are helping their students "find the forest" after many years of just "looking at the trees."

The Meaning of Interdisciplinary

Whenever we ask a student to write their thoughts on a topic within a given content area, we are in effect teaching using interdisciplinary methods. The skills we learn in language arts are applied in our need to communicate thought. However, interdisciplinary instruction as presented in this thesis is much more in-depth and seeks to create synergy between disciplines.

To begin the discussion, we look first at how interdisciplinary teaching is defined. According to the Center for Educational Research and Innovation, interdisciplinary is defined as "an adjective describing the interaction among two or more different disciplines. This interaction may range from simple communication of ideas to the mutual integration of organizing concepts, methodology, procedures, epistemology, terminology, data and organization of research and education in a fairly large field (OECD, 1972, pp 25-26)."

"Inter" signifies between, among, mutuality, reciprocity. Interdisciplinary is the most widely used term and the term most used indiscriminately. A similar term, multidisciplinary, signifies combination and is taken to mean studying in more than one discipline at a time. Both implies crossing between boundaries (Dillon, 2008). Curriculum mapping is an example of multidisciplinary applications in primary and secondary education. To ensure and support literacy in all disciplines, frameworks can be established that are centered on core goals (content standards, learning processes, and pedagogical beliefs) for all disciplines (math, science and art) and supply teachers an organizational structure to work within. The benefit for this type of approach is the incorporation of differentiated learning and opportunities for hands on engagement to build upon what is already known (Bintz and Moore, 2007).

Within the post-secondary arena, there are two schools of thought on the subject. The first states that interdisciplinary teaching is part of an educational framework to instruct students to see through more than one disciplinary point of view. Effectively this is the mission of a liberal arts education. Students are given a broad background in a coordinated manner that allows the student to understand knowledge from many fields of study. Most are familiar with this concept, but in this definition, the responsibility of linking the knowledge gained is placed upon the student to make meaning of his or her own learning ("Defining interdisciplinary," 2009).

The second point of view states that interdisciplinary thought is a necessity in a post-modern world in order to solve social problems that cannot be addressed by one point of view alone. Knowledge is being added at an ever increasing pace, and proponents of this thought state that specialization does not allow for seeing developments in other areas that may overlap. As a consequence, important discoveries may be missed ("Defining interdisciplinary," 2009). It could still be argued though that on the post-secondary level, coursework is still treated as a concrete set of discrete items instead of a holistic or dynamic process. In a series of essays written by academics from Alverno College, it was fundamentally agreed that it was important for all disciplines to embrace relevance in the real-world (Riordan and Roth, 2005).

One specific example was found in the integration of related disciplines into a core subject with a comparison of “stand-alone” critical thinking courses with those that integrate critical thinking skills within their primary courses. Understood as a major goal of all educators, it is agreed that critical thinking skills must be taught but the question of how best to teach these skills is still debated. Hatcher (2006) disputed claims that there was minimal difference in student achievement when critical thinking skills were integrated in other courses within various disciplines including math and science. He reported that in his study, integrating specific critical thinking skills into various subjects yielded greater pre- to posttest gains on standardized testing over teaching these same skills in a stand-alone critical thinking class. The limitation appeared to be in gaining the cooperation of faculty to teach the skills within their specific discipline.

A practical definition of interdisciplinary teaching could then be stated as "a way of approaching curriculum by organizing content and processes from more than one discipline around a central theme, issue, problem, topic or experience" (Jacob, 1989). In the previous example, the central theme would be critical thinking skills as applied to each specific discipline, thus increasing the chances that the students would show higher achievement.

Science education is an excellent example where integration into other disciplines is seen as a necessity. In an editorial written by Meredith Park Rogers and Sandra Abell (2007), the authors address the importance of connecting science with other disciplines to improve learning all subjects better. Recognized by the National Science Education Standards (NRC 1996), interdisciplinary teaching is seen as a means to strengthen student learning of science. The authors own literature review points out that integrated curriculum has support from cognitive science with emphasis that learning within a big picture is more powerful then learning in fragments. As such, learners construct stronger meaning within an interdisciplinary approach. In a study of British elementary students, science and social studies were integrated within a unit on Antarctica. Students were able to approach the subject on more than just one perspective thus increasing their opportunities to learn. This also had the advantage of allowing for student differences in how they learn. The result was that students had multiple ways to encounter the knowledge and as such were able to make more complex associations thus creating the potential for more effective learning (Nuthall, 1999).

In an interesting example of using unrelated disciplines to work together, mathematical ideas are used to teach English. Concept maps and graphic organizers can be used to help students keep track of the relationship of characters to plot and setting. Writing is taught by paralleling the construction of paragraphs with algebraic equations (Seo, 2009).

For all the positives that interdisciplinary instruction can have on students, there are cautions that need to be addressed. The primary concerns stated by Park Rogers and Abell (2007) included primarily a blurring of disciplinary boundaries leading to a devaluation of the content from both disciplines, thus making learning superficial. An equal concern is that when teaching in an integrated manner, the instructor's discipline would receive greater emphasis.

In a very elegant approach to interdisciplinary teaching, Bopegedera (2005) demonstrated the use of team teaching to minimize this problem. When teaching students about the science of light as it is applied to art applications, both science and art instructors took part in the other's lectures and projects. In so doing, both instructors were treated to the same content as their students as well as demonstrated that it was acceptable to try new things. By being present, instructors were also able to develop a full picture of how their instruction would affect the others and offer a form of control check. A second benefit was in building student confidence when the "other teacher" was present in a subject that they were not the expert on. This juxtaposition between student and teacher further strengthen the bond between "need to know" and "okay to know."

Team Teaching

Based on our original definition of interdisciplinary, there is a continuum between informal exchanges of ideas to that of teaching teams made up of faculty from different disciplines (Lattuca, 2002). That said, successful team teaching involves a great deal of collaboration and as such has its natural detractions. Primary and secondary teachers have limited time to plan unique, full courses. Additionally, there is often little support from administrators to allow for unique electives. Despite the risks, the gains that come with building relationships across academic disciplines can be greatly beneficial (Childers and Lowry, 2004). According to Childers and Lowry (2004) it is important to keep a fundamental list of questions forward to address the content that is to be taught. Such questions included what the team's focus would be, and would this encourage learning in the areas of science, history and the fine arts? One of the most important benefits stated was in the sense of shared commitment. Teachers are more often than not, isolated from one another and rarely have the time or opportunity to discuss their classroom practices.

Another advantage of faculty collaboration is in the form of creating learning communities. Social bonding of middle school students has been a primary advantage given for the support of interdisciplinary teams. Jensen (1998) had noted a correlation between sense of belonging and success. Students that did not enter the mainstream via participation on school activities were more likely to develop a sense of alienation (Wallace, 2007). Teachers are taught methodology for building learning communities with the classroom, but within interdisciplinary settings, the question of how do faculty fit into the learning community is an important question to address (Thomson, 2007).

The key to success both in Childers and Thomson's view is frequent communication and feedback from all faculty members. Trust is a major factor as faculty must be free to express views based on their discipline as well as discuss their teaching techniques. By providing feedback the team lead course can be kept fresh and innovative.

Another consideration for a true collaboration is the importance that the students not see one teacher as the "science guy" and the other as the "writing guy." To lesson this problem, collaborative teachers sat in and interacted with each other, providing support to the teacher in the lead position then switching roles when it was the other's turn to lead. While teaching pre-service science teachers how to make identification in the wild of various plant species, the pedagogy instructor would spell out management techniques to keep the class together and managed while the science teacher would be identifying the Latin names of the plants ("Co-teaching to cover pedagogy, content," 2009).

One of the most important benefit of team teaching not previously mentioned is the modeling students see of how to work in collaborative teams. Indeed this has been a common concern of in the United States as business in general have clearly stated that graduates from both secondary and post-graduate institutions have been ill prepared to deal with the challenges of working within multidisciplinary teams (Sevier, 2008). In a similar situation, British engineering students were being graduated in mono-discipline cohorts that were in effect ignorant of other areas of engineering. Feedback from companies that were hiring these graduates indicated a growing aggravation by employers who felt they were losing time and money to educate individuals on the other members of the teams they would join. It was also noted that as whole, graduates were not adequately prepared to work within heterogeneous teams. As a consequence, it had become necessary to introduce interdisciplinary training as a means to provide students with this fundamental skill. Faculty from various engineering disciplines with the overall goal to ensure balance across tasks, within groups and staff support across disciplines (Harrison, 2007).

Combining Art and Science

In an era of specialization, it has become increasingly clear that today, a liberal arts education is viewed as preparing students for the real world. U.S. Labor Department statistics state that the average American will change careers nine times in his or her lifetime (Wilson, 1995). The consequence of this statistic is that workers of the future require “seeing the big picture” so that they may adapt to changes beyond their individual control (Needle, et. al. 2007).

Curriculum integration has become increasingly important as school districts seek to reform their current curriculum to meet 21st century demands. The sheer volume of information gained on a daily basis means that much of what is taught today will be obsolete within the next decade. It is clear that integration between academic and related arts courses is essential for preparing students to think “outside the box” (Barry, 2008).

Never has this been most deeply felt then by secondary educators in many states including Tennessee. The Tennessee Diploma Project (Sevier 2008) is an attempt to prepare adolescence for a society that has seen information increase and change more rapidly than any time in previous history. As a consequence of this initiative, the traditional vocational path has been phased out in favor of a college-readiness program that allows for career technical electives or CTEs. For this reason, it would be of great benefit for academic as well as career technical teachers to develop collaborative efforts to meet the state demands.

Science and art are two disciplines that mesh together in a natural and holistic manner. From early history, science and art have been seen together in many ancient cultures such as the Mayans (Bopegedera, 2005). John Dewey (1934) commented that “even in the caves, human habitations were adorned with colored pictures that kept alive the sense experiences with animals that were so closely bound with the lives of humans” (p. 7). The Renaissance period was a time of enlightenment and interdisciplinary training. No one better defined this then Leonardo da Vinci who was artist, scholar and inventor. Biology teachers today still use “The Vitruvian Man” to teach anatomy using blackboard illustrations similar to what was done 100 years previous. This experience engages the students in artistic representations that involve the audience during the lecture as well as aid the instructor in the organization and flow of information (Babaian, 2009). In a similar study, an instructional approach to integrated science with the visual arts began with an understanding of da Vinci’s illustration and lead to constructing full size, three dimensional human skeletons using recycled materials. The premise behind this teaching approach is that in both art and science there is required higher-order thinking, creative problem solving and adaptive dialogue between the student and materials. Students were asked to create a full size skeleton after fully comparing the proportions represented by da Vinci’s illustration (the ideal) with their own proportions. Material choices for constructing the skeleton were based on what best fit the purpose for form and function (Petto and Petto, 2009).

In an extremely unique example, professors of molecular bioscience noted that as the scientific literature continued to expand, textbooks in an effort to maintain a manageable length, were becoming further and further removed from important societal topics that included ethics, history and public policy. The authors of this article presented a strategy that combined a multimedia presentation based on the television show, “Night Gallery.” One author portrayed the late Rod Serling, while the second author created three paintings to use as the exhibit, along with a film presentation that linked each painting to a specific. The professors’ use of the unexpected in the class served as a memorable way to teach students the fundamental concerns of ethics in microbiology. The lecture consisted of three mini-lectures with each of three paintings representing a point in history where microbiology had negative consequences to provoke further discussion. The presentation was not without problems however as students overall enjoyed the experience, but found they became too involved in the theatrics and less involved in the details to remember. The authors acknowledged that there was need to alter the presentation so as to not lose the purpose of the presentation, but despite this criticism, the authors believe the over goal was achieved (Dahl and Mixter, 2008).

The above examples serve to illustrate the use of interdisciplinary teaching by a single instructor or group of instructors within the same discipline. However, many examples have been published that utilize the expertise of faculty from both science and art programs. With regard to the specific discipline of chemistry, there is a fundamental link behind the chemical properties of elements and compounds with direct art applications such as pigments and light that make collaborative teaching very desirable.

Durability is not the only factor of importance to the artist. Function is often as important if not more so then form and beauty. In a true collaborative effort, a secondary chemistry and art teachers worked together to teach thermodynamics, ceramics and the culture of nomadic tribesmen in northern Nigeria. Introduced in 1995 by Nigerian teacher, Mohammed Bah Abba (Mohammed Bah Abba, 2000) the zeer pot has become an inexpensive method for providing refrigeration in arid climates. After learning how the zeer pot worked based on evaporation (thermodynamics,) students designed and created their own ceramic pots using the school kiln and under supervision of the art instructor. Working in groups, students received a grade based on their overall design and creativity for their ceramic course, and then used the finished pot to conduct individual investigations on their effectiveness as a refrigeration unit. Students compared their individual designs for effectiveness with various foods and presented their findings to the class (Breslyn, 2007).

Methodology and Procedures

Interdisciplinary teaching has been explored on the post-secondary level within and across university departments as academics embrace the "need to know" principle as a powerful motivation tool. Although evidence exists of interdisciplinary teaching at all levels of K-12 education, there is little to suggest the effects of a coordinated effort between the faculty of academic and career-technical programs. If we are to meet the strict requirements of the Tennessee Diploma Project, it will be important to tap into all the resources available to secondary educators for students to relate the importance and need of higher academic content to future real world employment. The purpose of this research was to determine if there was value in introducing team-taught interdisciplinary programs on the secondary level between academic and career technical teachers.

The high school selected for this study was a comprehensive four-year high school enrolling 1250 students in grades nine through twelve. The school opened in the fall of 1971 and graduated its first senior class in the spring of 1972. The Southern Association of Colleges and Schools and the College Board accredit the school.

The state report card for 2009 summarize that 46% of the students taught were considered economically disadvantaged with 17.3% qualifying under Title 1. Over 96% of the families are white with the remainder being of minority status. The secondary school in which the study was performed mirrors the county percentages with the exception of having closer to 49% economically disadvantaged. For this reason, many of the district's students were considered at risk for drop out or likely not to pursue further education beyond the secondary level. Specifically for the high school under study, the average senior class size is 300 students with

61.1% of the graduates enrolled in a post-secondary institution (four year college or university, community college, or technical school) on a full time basis.

The students selected for this study were enrolled in the advance art/photography class offered to junior and senior art students only. The class was a mix of 17 students of varying science background. Most of the students had already completed at least one year of high school chemistry. A few had completed or in the process of completing two full years, and a few had no formal high school chemistry experience. Students were divided by their years of chemistry experience and randomly selected to create groups that mirrored the experience of the whole class. Seven students were selected to compose the experimental group and the remaining ten composed the control group.

Data were collected from both experimental and control groups using a rubric. The experimental group participated in chemistry class while the control group did not participate. Both classes were then combined in a photography class where the projects were graded using a rubric. Criteria areas included the following six areas.

- **Craftsmanship**. Assessed how well the student followed the procedure in a manner consistent with the technique studied.
- **Concepts taught.** Assessed how well the student could explain orally and in writing the historical context, the physical processes and understanding of what role the chemicals played in creating the final product.
- **Creativity.** Assessed how well the student's personal voice came through using the assigned procedure.
- **Composition.** Assessed how well the student applied design elements and principles to the overall product.

- **Participation.** Assessed how involved the student was during class time to keep the room a safe and clean area to work in as well as showed respect for other student's work
- **Time and Effort.** Assessed how effectively the student used the given time allotted to complete the project including effort shown outside of class time.

Procedures

Approval for the project was granted by the principal of the school, and notification of intent and request for consent letters were sent home to the parents. Students were informed that they would be assigned a project based on the Van Dyke Brown process that would involve some of them participating for a brief time in chemistry prior to all the students working together on the project. Students and parents were informed that participation was voluntary and student grades would not be affected for the current six-week term or for the semester.

After division into the control and experimental groups, the experimental group students were sent to participate for three days in a Chemistry I class. During this period, students were given a historical perspective of the Van Dyke Brown process as well as given the opportunity to perform experiments related to the project and examine the different effects that could be created by adjusting the chemical composition of the solutions and the exposure times of the image. Students in the control group remained in their photography class and were given the same historical background information without the specific chemistry information and activities. After completion of the chemistry portion, the experimental group rejoined the control group and the students were assigned a specific photography project using the Van Dyke Brown process that the students in the experimental group had learned about previously.

Quantitative data obtained from the art instructor's rubric were used to assess each student's submission and to determine if there was a significant difference in scores within specific rubric categories and overall scores of the experimental group verses the control group.

Research Questions

Three research questions were used to guide the analysis of data.

- **Research question 1.** Is there a difference in overall scores earned between art students who are given a more in-depth background of the materials to be used in a photography assignment than those who are not?
- **Research question 2.** Is there a difference in scores earned between art students who are given a more in-depth background of the materials to be used in a photography assignment than those who are not when assessed on their understanding of the concepts taught?
- **Research question 3.** Is there a difference in scores earned between art students who are given a more in-depth background of the materials to be used in a photography assignment than those who are not when assessed on their craftsmanship?

Each research question was followed by a research hypothesis. All three research questions were analyzed using independent-test. The results of all three questions yielded significant results as indicated respectfully $t(10.482)= 4.922$; $t(13042)=2.430$; $P<.05$; $t(15)=5.557$, $P<.05$. The results are displayed in the following tables:

Table 1

Independent t-test on the overall scores for experimental and control groups

Group	*M*	*SD*	*df*	*t*	*2-tail Sig.*
Experimental	23.43	0.787	10.482	4.922	0.001
Control	18.20	3.225			

Note. $p < 0.05$

Table 2

Independent t-test on scores earned for criteria, concepts taught, for experimental and control groups

Group	*M*	*SD*	*df*	*t*	*2-tail Sig.*
Experimental	3.86	0.378	13.043	2.430	0.030
Control	3.10	0.876			

Note. $p < 0.05$

Table 3

Independent t-test on scores earned for criteria, craftsmanship, for experimental and control groups

Group	*M*	*SD*	*df*	*t*	*2-tail Sig.*
Experimental	4.00	0.000	15	5.557	0.001
Control	3.00	0.471			

Note. $p > 0.05$

Discussion

In regard to Research Question #1, Is there a difference in overall scores earned between art students who are given a more in-depth background of the materials to be used in a photography assignment than those who are not? An independent t-test revealed a significant difference between the experimental and the control group $t\ (10.482) = 4.922$, $p < 0.05$. Therefore the null hypothesis was rejected.

Students who were chosen to be in the experimental group were given no forewarning as to what they would be experiencing other than to be told that they would be learning how to make the solutions used in the Van Dyke Brown photography process. Once combined with an existing chemistry I class, the students were taught not only the historical basis of the process, as was their peers in the control group, but were also drilled on their knowledge of associated vocabulary and allowed to participate in hands on experiments that demonstrated the behavior of the chemicals they would be using. Therefore this experience gave them advantage over the control group.

In regard to Research Question #2, Is there a difference in scores earned between art students who are given a more in-depth background of the materials to be used in a photography assignment than those who are not when assessed on their understanding of the concepts taught? Again the results indicated a significant difference between the experimental and the control group $t\ (13.042) = 2.430$, $p < 0.050$. Therefore the null hypothesis was rejected.

The criterion of concepts taught was the most noted difference in favor of the additional background information. Students were given an incentive to learn the vocabulary and the related chemistry because it would affect how they would handle the assigned project in their photography class.

Students experienced firsthand the reduction of silver when exposed to UV-light as well as the balancing effect of using photographer's hypo solution for removing of excess silver chloride. Students also were allowed to see how silver can reduce from its ionic state to its metallic state by putting copper metal in a solution of silver nitrate. Finally students were shown the various effects that photographers are able to produce by using additional reducing agents to create different toned appearances. This final step of toning was based on the same chemistry, but with different metals. Students were allowed to view a variety of vintage and modern prints created by the Van Dyke Brown process and encouraged to discuss how different toners created different moods, and why color printing may not create the same mood to the viewer as the method under study was capable of.

Students reported that they better understood why they needed to perform certain steps in the development process, and they were all interested in the various moods that could be created by using different metals to tone their final print. All felt the experience was enjoyable and they looked forward to trying the process out in their art class. Additionally, students were able to correctly answer questions over the history, vocabulary and chemistry learned two weeks after the additional instruction was given.

In regard to Research Question #3, Is there is a difference in scores earned between art students who are given a more in-depth background of the materials to be used in a photography assignment than those who are not when assessed on their craftsmanship? The results of an independent t-test revealed significant difference between the experimental and the control group $t(15) = 5.557$, $p < 0.05$. Therefore the null hypothesis was rejected.

Observation of the students while working on their projects by the art instructor showed some very interesting findings. Two of the students who were in the experimental group were reported by the art instructor to have become peer-mentors to students who were in the control group. What was even more encouraging, was one of the students who was mentoring had been one of the students who had not taken chemistry formally, and had never voluntarily helped other students before. It is believed that the attention given to her to teach her the background information not only improved her pre and post test scores on the vocabulary learned (see Appendix D for pre and post test data scores) but instilled in her a level of confidence that she felt enabled to help other students who were having more difficulty with the assignment. Additional comments from the art instructor indicated that several in the experimental group made more effort to choose their subjects to be more in keeping with the assignment. One specifically chose an image of two young girls that was slightly out of focus to create the illusion of a much older negative.

The findings from the conducted research were consistent with the findings of Bopegedera (2005), Furlan et. al. (2007), Barry, (2008), Eisenkraft, Heltzel, Johnson and Radcliffe (2006), and Petto and Petto (2009) that confirmed the "Need to Know" principle as a major driving force behind the success or failure of this investigation. Students, who are not motivated to learn, will not be vested in taking responsibility for their own learning and as such not be as successful as those that do (Bulte and Westbroek, 2006). Before students appreciate what is presented to them, there has to be a connection between the topic at hand and how that information will affect success in a second, related topic. Secondary students tend to compartmentalize their experiences into subject areas, primarily because secondary education presents those topics in compartmentalized departments. High stakes testing fosters that belief by requiring the need to master specific topics in a given area for graduation. In a sense, the "forest is lost for the trees" in the minds of students. The findings of this study indicate that there is definite improvement in photography project scores for students that are given additional information and experience in the related discipline of chemistry.

Conclusions

The purpose of this study was to determine the effects of performance of secondary art students participating in an interdisciplinary chemistry-art program with those taught in an art only program. Three independent t-tests were conducted. All three tests indicated a significant difference between the group that received the additional instruction and the group that did not. Therefore, the inference can be made that team teaching between related disciplines does affect the performance of students given a related assignment.

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