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ABSTRACT

This study examines how academic assertiveness in junior high school students affects conceptual change and the degree to which their assertiveness affects the conceptual change of partners paired with them for a series of activities using a computer simulation of the human cardiovascular system. The sample was a group of 90 eighth-grade students in a life science class. Students were randomly assigned to dyads, and dyad members used the simulation as an exploratory vehicle for resolving questions about 12 cases. A measure of academic assertiveness was completed for each student by the teacher. Ratings of assertiveness by the teachers were consistent with behaviors exhibited by the students. Typically academically assertive behaviors were making suggestions to partners, challenging partners' interpretations, and physically appropriating the computer's keyboard and mouse. Regression analyses showed that assertiveness did not play a role in the conceptual change posttest score, but the assertiveness of an individual's partner was inversely related to the individual's score, even after pretest score and self-efficacy beliefs were accounted for. Socially assertive behaviors may result in greater attention to the task and are also indicative of greater intellectual engagement. These results suggest that students with similar levels of assertiveness should be paired for dyad work. Observations showed that less assertive students were passive observers, and unless they were paired with students with similar levels of assertiveness, they would not be prompted to take any initiative in a relatively ill-defined learning environment where shared interpretations and joint decisions are necessary. (Contains 1 figure, 4 tables, and 41 references.) (SLD)

Using Simulations in the Middle School: Does Assertiveness of Dyad Partners Influence Conceptual Change?

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When assigning students to work in pairs during laboratory exercises, instructors intend that members of these dyads facilitate each other's learning through meaningful dialogue and shared insights. In these cases, learner characteristics such as ability or degree of prior knowledge can affect not only the individual's learning but also the achievement of other group members (Carter & Jones, 1994; Webb, 1992; Tudge, 1991). There are, however, additional influences that complicate the picture of how learning takes place in pairs or small groups. Attributes such as confidence in one's ability (Tudge, 1990), self-efficacy (Bandura & Shunk, 1981) or perceived academic status (Cohen & Lotan, 1995), affect not only an individual's learning but the learning of group members as well. The context of group learning also affects how learning occurs; the language used, the non-verbal communication, the nature of the tasks and specific roles of individuals all shape interpersonal interaction and the consequent character of understanding attained by group members (Rogoff, 1984).

The influence of attributes such as ability or self-efficacy, or the way in which language is used in a group setting, may be affected by the degree of willingness individuals exhibit to act upon their ideas-- to assert themselves in group settings. Assertiveness is characterized by the ability to express thoughts or feelings without violating the rights of others, and unassertive behavior by submissive or withdrawn behavior (Gerler, Peeler & Rimmer, 1981; Alberti & Emmons, 1974). Individuals with ample ability and self-efficacy in science may lack the assertiveness to function productively in settings where interpersonal interaction is essential to developing understanding. Furthermore, the effect of this situation may be amplified when students are involved with computer-based simulation activities designed to effect conceptual change. These activities require joint decision-making about methods of testing hypotheses within the simulation, verbal sharing of one's views of why certain phenomena take place, and they often require refutational exchanges among group members. This study examines how academic assertiveness in junior high school students affects conceptual change, and the degree to which their assertiveness affects the conceptual change of partners paired with them for a series of activities using a computer simulation of the human cardiovascular system.

Background

There are many personality constructs that describe social behavioral tendencies such as extroversion (Eysenck & Eysenck, 1968), sociability (Cattell, 1965), and social dominance (Cohen & Lotan, 1995). These characteristics predict, to some degree, specific behaviors that influence learning in group situations such as answering a partner's question, giving unsolicited hints, or stating how to solve a problem (Amigues, 1988; Carrier & Sales, 1987; Collins, 1970; Latane, Williams & Harkin, 1979; Johnson & Johnson, 1979; Reid, Palmer, Whitlock, & Jones, 1973; Sutter & Reid, 1969). However, when trying to translate these findings on attributes and group interaction to practical application in classroom situations, two problems arise. The first is that these constructs are not designed to address the simple expressive behaviors associated with dyad work during computer-based conceptual change activities--verbal behaviors such as stating one's opinions, offering suggestions, or explaining ideas, and non-verbal behaviors such as appropriating the use of tools (keyboard and mouse, lab equipment) and taking the initiative to determine the kind of information recorded for the dyad in laboratory notebooks (Windschitl, 1996).

For this study, the tendency for students to express themselves through words or action in a dyadic learning situation is termed "academic assertiveness". Behaviors associated with academic assertiveness often result in dissonant interactions (not recognizing others' poor ideas, criticism of one's own ideas, and criticism of others' ideas), as well as consonant interactions (jointly constructing an argument or offering explanations) between partners. These behaviors have been shown to help students confront their own misunderstandings (Dickinson, 1985), reorganize their approach to problems (Bearison, Magzamen & Filardo, 1986; Hatano, 1986; Piaget, 1970), and generate conceptual change (Lumpe & Staver, 1995). Being "direct without hedging" in group learning has also been indicative of effective communication among students (Damon, 1984). On the other extreme, students who are withdrawn from interactions with others may not recognize when they misunderstand something, and may not have correct conceptions reinforced by their own participation (Noddings, 1985; Webb, 1982).

Assertiveness is conceptually related to the constructs of self-confidence and self-efficacy. Learners who have ability in certain areas may or may not have the self-confidence to interact with or give explanations to partners. In a study of children paired for a series of exercises in which they predicted the operation of a balance beam, Tudge (1990) found that learners with more advanced thinking did not necessarily have a higher confidence level than those students with less sophisticated thinking. Furthermore, those students with higher ability but less confidence, tended to regress in their thinking when paired with students who used less sophisticated rules but had more confidence in their predictions.

Self-efficacy is a more general measure of confidence; it is the belief in one's capabilities to organize and execute the courses of action required to manage prospective situations (Bandura, 1997). Self-efficacy mediates the effects of skills on subsequent performance by influencing effort, persistence, and perseverance (Bandura & Shunk, 1981; Bouffard & Bouchard, 1990). Efficacy beliefs are related to performance, but they have not been studied extensively in the context of group work (social interaction), nor does it seem that self-efficacy is directly connected to many behaviors commonly associated with group computer-based work by young learners. However, because it appears to mediate between ability and success in academic tasks, self-efficacy was assessed in this study and examined in its relationship with prior knowledge, assertiveness and degree of conceptual change.

A second problem in translating findings on attributes and group interaction to classroom situations is a logistical one. Teachers, without the help of psychometricians, do not have the skills or time necessary to assess the degree to which their students possess psychological characteristics. If, for a class activity, there are optimum matches between individuals with certain levels of social dominance or extroversion, the teacher would have to administer and interpret instruments that measure such traits before deciding how to pair the students. To address the practical classroom application of research findings, as well as examine the effects of assertive behavior, this study used a simple teacher-based measure of assertiveness (described later). Then, if associations were found between assertiveness, partners' assertiveness, and conceptual change, teachers themselves may have a simple measure by which to validly assess what types of individuals would work together well with regard to assertive tendencies.

Alternative Conceptions

Learners often hold alternative conceptions about natural phenomena that influence their learning of science; the impact of such alternative conceptions has been described in areas such as electric circuits (Dupin & Joshua, 1987), chemistry (Krajcik, 1991), the reflection of light (Mohapatra, 1988), and simple mechanics (Viennot & Rozier, 1994). Informal ideas often have tremendous explanatory power in the mind of the student, despite having the general characteristics of being poorly articulated, internally inconsistent, and highly dependent on context (Driver & Easley, 1978; Hewson & Hewson, 1983; Posner, Strike, Hewson, & Gertzog, 1982; Pines, 1985). In many cases, this explanatory power makes such informal ideas highly resistant to change.

Mintzes, Trowbridge, Arnaudin and Wandersee (1991) questioned students in fifth, eighth, and tenth grade, as well as college freshmen/sophomores about the cardiovascular system. At every grade level, most students understood that the heart pumps blood (65-80%), but as many as a third at each level suggested that the heart also cleans, makes, filters, and stores blood. Except for college biology majors, fewer than a third of those questioned understood that the right side of the heart pumps deoxygenated blood, and many students failed to acknowledge in any respect that the heart acts as a double pump. When asked to select from several illustrations which heart was most like their own, three- and four-chambered hearts were chosen in equal numbers by the middle school and high school students. Few students among those who chose the four-chambered heart as a model could explain the function of the chambers. This finding supports the assumption that anatomical knowledge has limited connection with a broader functional conceptualization of how the circulatory system works.

When asked to select an illustration that describes the path of blood in the body, the students' most frequent response was an incorrect pattern in which blood flowed from the heart to an extremity then back to the heart, not including any flow to the lungs. There was a trend towards selecting the correct circulatory pattern (including systemic and pulmonary circulation) with increasing age.

An earlier study of 495 students from fifth grade through college revealed findings similar to those of Mintzes et. al (Arnaudin & Mintzes, 1985). Approximately 40% of elementary age students believed that the heart has three chambers. When asked to identify the function of the heart, most respondents indicated that it pumped blood, but a significant minority (17%-35%) ascribed additional functions to the heart (storing, filtering blood). Most students had difficulty conceiving of the heart as a double pump; this notion was supported by interview data in which students frequently asserted the heart pumped either oxygenated or deoxygenated blood, but not both. Students were also asked about the relationship between the heart and the lungs. When asked "Where does air go after it enters the body?", approximately one-third of elementary and secondary students selected a diagram that depicted "air tubes" connecting the lungs and heart.

Method

Research Questions

The first research question of this study was: After accounting for prior knowledge and efficacy beliefs, does academic assertiveness predict the degree of conceptual change in individuals? The second question investigated was: After accounting for prior knowledge and efficacy beliefs, does the academic assertiveness of dyad partners predict the degree of conceptual change in individuals? And finally: What were the behaviors exhibited in the dyadic interactions, and were the behaviors observed consistent with the teacher ratings for the individuals?

Sample

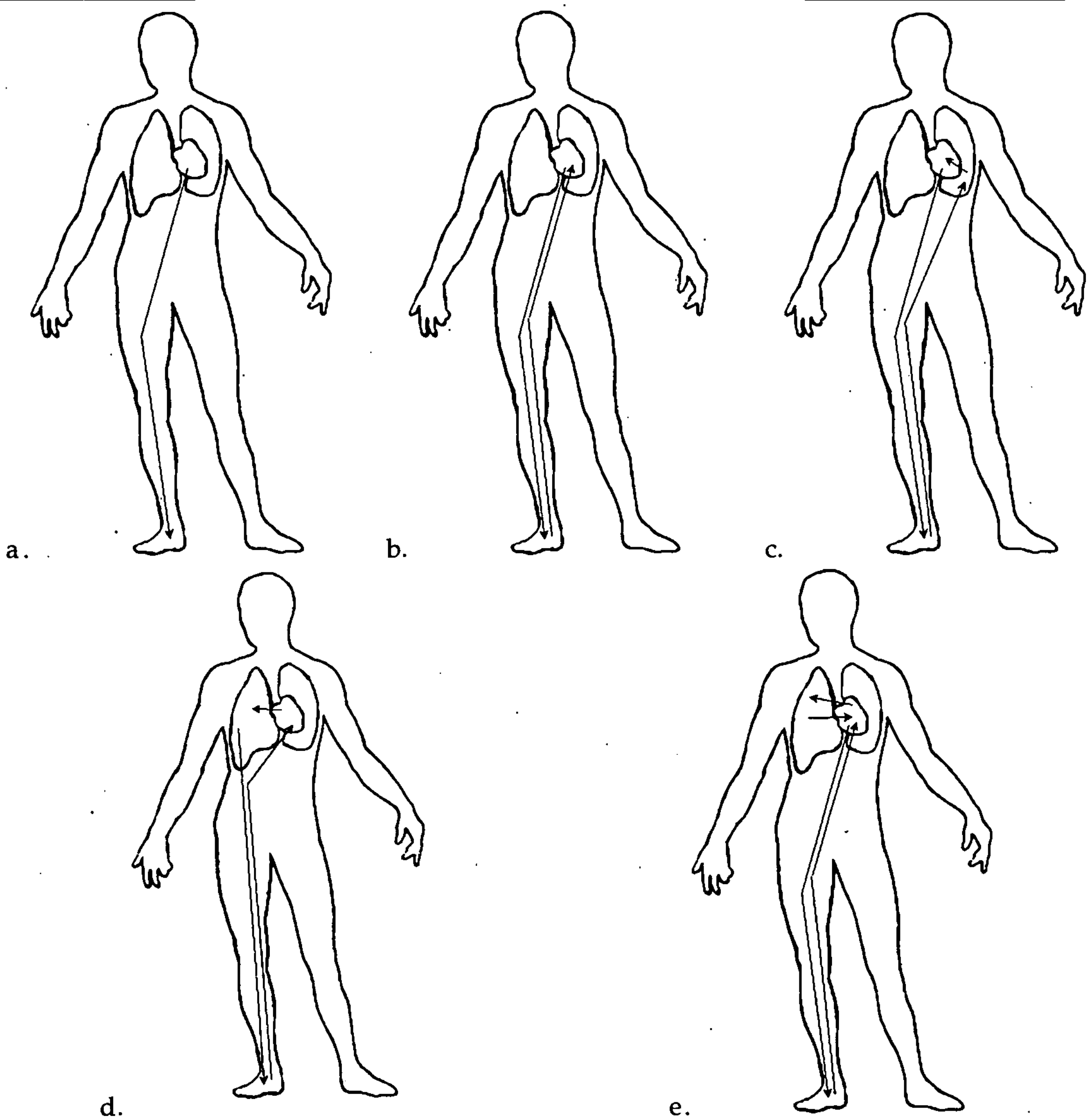
The study was conducted in a public suburban middle school. The sample was group of 90 eighth-grade students enrolled in a life science class. The students participated while remaining in their regularly assigned class sections-- three sections of thirty students each.

Design

The instructional component of this study was designed to effect conceptual change about the structure and function of the human cardiovascular system. Alternative conceptions were identified from a pilot study and from related studies of alternative conceptions about the human cardiovascular system (Arnaudin & Mintzes, 1985; Mintzes, Trowbridge, Arnaudin, & Wandersee, 1991). Topics found to be particularly generative of alternative conceptions were incorporated into a written student guide that was used by students in a series of explorations. The explorations were based on a computer simulation of the cardiovascular system. Before this series of activities, participants were assessed as to their existing conceptions of the human cardiovascular system and sense of self-efficacy about their science ability. Students were also rated on their assertiveness by three teachers with whom the students regularly worked. Students were then randomly assigned to pairs for the exercises and, after a week of such exercises, were given a posttest to assess their conceptual change. The posttest scores were regressed on using the following predictors: pretest scores, self-efficacy rating, assertiveness rating, the assertiveness rating of the individual's partner, and the partner's self-efficacy rating. Additionally, nine pairs of students were videotaped for approximately three hours apiece during the exercises.

Assessments of alternative conceptions

The pretest was a 22-item multiple choice instrument with questions derived from relevant literature on misconceptions. The general topics addressed by these questions were: the effects of physical activity on blood flow, pattern of blood flow through the circulatory system, blood flow to the brain, movement of oxygen through lungs and heart, structure of the heart, and blood flow within the heart (sample question in Figure 1). The posttest instrument was a multiple choice test parallel to the pretest, using approximately the same number of questions.



7. Which diagram best shows the flow of blood after it leaves the heart on its way to a body part such as the toe?

a. The blood goes to the toe, and remains there. --(heart to toe)

b. The blood goes to the toe then back to the heart. --(heart to toe to heart)

c. The blood goes to the toe, then to the lungs, then to the heart. --(heart to toe to lung to heart)

d. The blood goes to the lungs first, then to the toe, then back to the heart. --(heart to lung to toe to heart)

e. The blood goes to the toe, then to the heart, then to the lungs, then back to the heart. --(double circulation)

Figure 1. Sample question from pretest. Adapted from Arnaudin and Mintzes (1986).

Assertiveness measure

Three teachers (science, math and social studies), who worked with the same three sets of thirty students in their classes, rated each student on a four-point assertiveness scale ranging from highly assertive ("consistently offers answers, suggestions, opinions to classmates in group learning situations") to highly unassertive ("never offers answers, suggestions, opinions to classmates in group learning situations", Table 1).

Table 1

Student Assertiveness Rating Scale

1) *Highly assertive*-- student shows high levels of participation and consistently offers answers, suggestions, opinions to classmates in group learning situations.

2) *Assertive*-- student shows moderate levels of participation and offers answers, suggestions, opinions to classmates in group learning situations.

3) *Unassertive*-- student shows low levels of participation and rarely offers answers, suggestions, opinions to classmates in group learning situations.

4) *Highly unassertive*-- student demonstrates almost no participation and never offers answers, suggestions, opinions to classmates in group learning situations.

Note. Instructors were asked to "Please assign the one rating number that best describes each student."

Note. Ratings were recoded so that higher scores were indicative of greater degree of assertiveness.

Self-efficacy measure

Knowledge, skill, and prior achievement are often poor predictors of subsequent learning because the beliefs that individuals hold about their abilities and about the outcome of their efforts powerfully influence the ways in which they will behave (Pajares, 1996). To account for this in the regression analysis, students were asked to complete an instrument measuring their self-efficacy beliefs about science ability (Table 2).

Table 2

Student Science Self-efficacy Rating Scale

1. Compared to others my age, I am good at science.
2. I get good grades in science.
3. Work in science class is easy for me.
4. I'm hopeless when it comes to science.
5. I learn things quickly in science.
6. I have always done well in science.

Note. For each question, students were asked to indicate the most appropriate response from: strongly agree, agree, neutral, disagree, strongly disagree.

Procedure

Students participated in their regularly-assigned science class sections, each of which was taught by the same instructor. Interviews with the teacher and comparisons of student grades revealed no systematic differences across sections. During the first class of Week 1, participants were given the pretest and completed the self-efficacy survey. Participants were also given a 30-minute overview of the cardiovascular simulation to acquaint them with the functions of the simulation so that they would be able to spend more time "using" the simulation rather than learning "how to use" it in subsequent class periods. For the remainder of the first week, students worked as individuals in independent and whole-class learning activities based on the cardiovascular system. None of the instruction during the first week directly addressed conceptual change topics that would be explored with the simulation exercise the following week. At the beginning of Week 2, students were randomly assigned to partners within their classes. During Week 2, students, together with their partners, used a descriptive guide and attempted to resolve 12 "cases" dealing with a hypothetical student whose ongoing health situations prompted students to generate hypotheses about cardiovascular phenomena. Student dyads were given a written guide that furnished context about each of the twelve cases and framed the questions to be resolved (Figure 2).

Case #7: Lynn is disappointed in the results of the treadmill test and plans to begin exercising regularly. Lynn asks the doctor if a person who becomes an athlete will see a change in heart rate or stroke volume when at rest. At rest, are there any significant differences between an fit and unfit individual concerning heart rate? stroke volume? Write your prediction here and explain briefly: Now test your prediction with the simulation. Briefly describe how you tested this case with the simulation, include specific numbers. State a conclusion.

Figure 2. Sample case from students' written simulation guide.

The dyad members used the simulation as an exploratory vehicle for resolving these cases. Students recorded predictions about phenomena within each case, formulated hypotheses about how to test their prediction with the simulation, and then found ways to test them. At the end of Week 2, students were given the posttest. The total amount of time spent with the simulation was about five hours.

Results

Internal Consistencies

The consistency estimate of the assertiveness measure was .82 (using Cronbach's alpha); the internal consistency of the science self-efficacy measure was .91 (using Cronbach's alpha).

Pretest and Posttest

The mean score for all subjects on the pretest was 10.6 or approximately 48% (22 was the maximum possible, SD= 3.05; Table 3). The pretest was used to identify areas of misconception as well as act as a covariate for later analyses. The posttest mean was 13.1 or approximately 59%

(23 maximum possible, SD= 3.83). For participants scoring above the mean for assertiveness (2.01 on a scale of 1 to 4), the pretest mean was 11.52 (SD= 3.48); for those scoring below the mean for assertiveness, the pretest mean was 10.04 (2.65). The posttest mean for those high in assertiveness was 14.04 (SD= 4.04); for those scoring low in assertiveness the posttest mean was 12.47 (SD= 3.62).

Table 3
Means and Standard Deviations for Pre- and Posttest Scores

	High Assertiveness			Low Assertiveness			Total		
	M	SD	N	M	SD	N	M	SD	N
Pretest	11.52 (52%)	3.48	42	10.04 (46%)	2.65	42	10.6 (48%)	3.05	84
Posttest	14.03 (61%)	4.04	42	12.47 (57%)	3.62	42	13.06 (57%)	3.83	84

Regression Analysis

To determine the influences of individual and partner assertiveness on conceptual change, a regression was run on the posttest scores. In the final regression stage, pretest score was the strongest predictor (Beta= .51, $p < .01$); science self-efficacy scores were significant (Beta= .25, $p < .01$); assertiveness rating of individuals were not significant (Beta= .16, $p < .11$), however, the assertiveness ratings of the partners was a significant negative influence on the individuals' posttest scores (Beta= -.18, $p < .03$; Table 4). Follow-up correlations were calculated, to check whether partners' prior knowledge about the cardiovascular system was related to individuals' posttest scores; they were not ($r = .01$).

Table 4

Multiple Regression: Posttest Score

PREDICTOR	B	Beta	t	p
Pretest score	.56	.51	5.04	.01**
Self-efficacy of student	1.22	.25	2.95	.01**
Assertiveness rating	.85	.17	1.62	.11
Partner's assertiveness	-.94	-.18	-2.14	.03*
Partner's self-efficacy	.61	.13	1.50	.14
Constant	10.63	3.68	.01	

* $p < .05$

** $p < .01$

Degree of conceptual change

For 16 of the 23 posttest questions, a greater proportion of students selected correct responses than they did on parallel pretest items. The largest gains were in questions dealing with the structure or purpose of parts of the cardiovascular system. When asked to select the correct completion for: Arteries are vessels in the body that..., 40% of students selected the correct response "transport blood away from the heart" when only 26% had done so in the pretest. When asked a similar question about veins, 60% answered correctly when only 39% had done so in the pretest. When asked "What is the relationship in blood pressure between arteries and veins?", 55% selected the correct response on the posttest "arteries always have higher blood pressure", when only 32% had responded correctly on the pretest. The largest gain was in response to a question accompanying five possible diagrams of the heart. Only 24% of students selected the correct four-chambered diagram on the pretest, however 72% selected the correct diagram on the posttest. This is a curious outcome considering that on a non-diagrammatic question asking how many chambers the heart has, 50% of students correctly chose "four chambers" on the pretest and 60% of students selected the correct answer on the posttest. Considering the dynamic nature of simulations and what many instructors hope to convey to students through hypothesis-testing and experimentation in simulated environments, it is rather unusual that the biggest gains in remediating alternative conceptions were made in structure or purpose of parts of the cardiovascular system rather than in more dynamic phenomena and relationships between phenomena in the system. In such a question, dealing with the pattern of blood flow in the cardiovascular system (shown in Figure 1), 24% of students selected the correct answer (indicating the understanding of a double circulation) on the pretest, and only 26% responded correctly on the posttest.

Observations

Analyses of the videotaped dyadic interactions revealed that those pair members rated as more assertive tended to be verbally active, consistently expressing what they were thinking. The members rated as more assertive articulated to their less assertive dyad partner what perceived relationships were evident to them in the simulated environment. Also, the assertive members suggested "what if" scenarios more often. Less assertive members of the observed pairs were often passive recipients of their more assertive partners' reasonings. Interestingly, the less assertive members did not appear to be less methodical or disinterested, in fact, they tended to focus on the stepwise completion of tasks in the written guide with few expressions about why or how phenomena took place. The following is an excerpt from about 27 hours of videotape; it features Scott (rated high in assertiveness) together with Jared (rated low in assertiveness). They are trying to trace the movement of a blood cell through the circulatory system.

Scott: OK, so you want to do something? (hands Jared the mouse).

Jared: What do I have to do here?

Scott: Go to "Stroke volume" (a screen to test hypotheses about the heart).

Jared: Yea! Stroke volume!

Scott: He's running slow, make him run faster (referring to simulated jogger).

Scott: He's tired... I think we're supposed to write something now. Go to the main menu, then to "Circulation" (takes mouse from Jared).

Jared: The blood cell started at the heart and ended at the lungs.

Scott: O.K. Let's try it again, it passes through the liver, it went through the lungs then...(pause).

Jared: Where did it end?

Scott: At the heart, but I predict now it's going to be the liver, what do you think?

Jared: The liver.

Scott: (Tests hypothesis with simulation) There it goes! It's the intestines then the liver.

(Scott writes the results in the written guide, Jared follows his lead).

This interaction does suggests contrasts between high and low assertiveness students, and the tendencies for the more assertive partner to have control of the mouse, to suggest interpretations of what they see in the simulation, and to initiate thoughts about hypotheses were present to some degree in all the observed pairs. Even though there was a great deal of consistency across teacher's ratings of the students' assertiveness, much of the activity observed between pair members could better be described as impulsive rather than assertive behavior. Students rated high in assertiveness tended to initiate activities in the simulation without consulting their partner, and jumped to conclusions without examining the evidence or discussing with their partner.

The quality of dyad discussion was consistently low. There were few deliberations of significant length, typically there were only a couple exchanges of ideas and these were not usually supported by reasoning or careful observation. This lack of productive discourse undoubtedly attenuates the prescriptive theoretical power of many aspects of group learning or conceptual change activities.

Student lack of persistence was also a problem during the study. Few dyads were able to maintain their focus on the simulation exercises for the duration of the second week. Some students rated high in assertiveness became bored with the activity, and withdrew from the activity, leaving the partner to finish the activities by default. Future studies of this type should not neglect the role of motivation in students for these kinds of extended learning activities.

Discussion

The ratings of assertiveness by the teachers were consistent with the behaviors exhibited by the students. Typically assertive behaviors were: making suggestions to partners, challenging partners' interpretations of what was happening within the simulated environment, and physically appropriating the computer's keyboard and mouse. Conversely, the less assertive individuals were more passive, and often acquiesced to directives given by their more assertive partners. The regression showed that assertiveness did not play a role in conceptual change posttest score for individuals. However, the assertiveness of an individual's partner was inversely related to the individual's posttest score, even after pretest score and self-efficacy beliefs were accounted for. It is likely that physically assertive behaviors such as taking control of the mouse and actuating decisions in the simulation result in greater attention to the task. Socially assertive behaviors such as suggesting courses of action and expressing one's opinions are also indicative of a greater intellectual investment in a task. These results suggest that students with similar levels of assertiveness should be paired for dyad work. The observations consistently showed that less assertive students are passive observers, and unless they are matched with students with similar levels of assertiveness, they will not be prompted to take any initiative in a relatively ill-defined learning environment where shared interpretations and joint decisions have to be made in order to progress. Observations also showed that, without coaching, students with high ability or high assertiveness will not spontaneously adopt the role of mentor relative to a less knowledgeable or less assertive partner. Very few helping behaviors were noted (giving hints, modifying rather than rejecting inappropriate suggestions, giving explanations) and the notion of mentor-apprentice relationships, in which the more able student scaffolds the developing understanding of the less able student, were not realized in any observed pairings. Finally, if assertiveness is a measure with which to pair students for conceptual change activities, then teacher ratings may be effective in assessing students levels of assertiveness. The consistency (alpha= .81) of the ratings across teachers was sufficient and the ratings did hold significant predictive power for posttest scores of dyad partners.

Could this learning experience be termed a success? Most educators would be disappointed in a 59% class average. However, this research was based on misconceptions; the assessment instrument contained items that, according to literature, represented persistent alternative conceptions in a majority of young learners. Therefore, the 11% gain (absolute) or 22% improvement (relative to pretest score) may indicate a greater success than first appears.

Conclusion

With the current emphasis on group learning in our schools, particularly in situations where computer stations are shared, this type of research can inform not only the design of learning activities, but also how classroom teachers might choose to group students for conceptual change instruction. Assertiveness, as a construct, seemed to be interpreted by several teachers with some consistency, as their agreement on student ratings was quite high.
However, assertiveness, like other psychological variables, is related to a host of similar constructs. Disentangling assertive behaviors from manifestations of other constructs as disparate as leadership and impulsivity is necessary to understand how learners affect each other's developing understanding.

Individual's assertiveness tended to be inversely related to their dyad partner's conceptual change. It is likely that behaviors such as taking control of the mouse and actuating decisions in the simulation are associated with greater attention to the task. Behaviors such as suggesting courses of action and expressing one's opinions may also be indicative of a greater intellectual investment in the task, however determining whether assertive behaviors cause greater intellectual involvement or whether they are the result of such involvement has yet to be determined. The results do suggest that students with similar levels of assertiveness should be paired for dyad work.
Individuals paired with others of higher assertiveness tended to have their degree of conceptual change compromised.

The deliberative discussions between dyad partners were impoverished, making the interactions difficult to study, and this undoubtedly suppressed the positive effects of the learning experience.

Students should be acquainted with how they can contribute to discussions that foster cooperative problem-solving. Students are too often exposed to science "exercises" in which there are quick answers and little need for extended, collaborative mental effort. Consequently, there is little need for extended dialogue and learners are left without this valuable social/intellectual experience.

The simulation exercise was moderately successful in remediating alternative conceptions, with the students' mean scores improving from 48% to 59%. It is reasonable to assume that if the learning objectives were focused on more common conceptual material about the cardiovascular system as opposed to material that has been shown to be the subject matter of entrenched alternative conceptions, the scores of students would have reflected larger gains in understanding.

Simulations certainly have a place in the science classroom; however, the quality of personal interaction and the type of inquiry that is stimulated with this technology is apparently of far greater importance than any qualities inherent in the technology itself.

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