Patterns of Risk Seeking and Aversion Among Pre-Service Teachers: Mathematical Decisions, Preference, Efficacy, and Participation

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Abstract

A constructivist approach to education demands that students engage in problems that elicit disequilibrium. In disequilibrium, it is believed, students will seek out meaningful new ways to integrate content-related information. It is also believed that willingness to engage disequilibrium is necessary for both students and teachers if constructivist approaches are to work effectively in the classroom. Using a risk-eliciting investment game, a survey of preferences, and a data-blind evaluation of participation in class discussion, we investigated the hypothesis that there are risk-seeking and risk-averse pre-service teachers and that this risk is conserved across activities. We found that there are strong correlations between risky behavior, risk preference, and willingness to engage in constructivist activities, both in class discussions and open-ended problems in general in science or mathematics. Approximately 65% of pre-service teachers only engaged in discussions when directly asked a question and these teachers also strongly preferred non-constructivist mathematics and engaged in 'safe' behavior in the investment game. Risk-seeking students in the game were more likely to engage in discussion and preferred open-ended and confusing activities. Gender was not associated with student's risk preference except males were more prone to seek open-ended science activities. In general, the results strongly suggest that risky behavior is associated with constructivist-type activities and that there are general metrics for risk that carry over across activities.

"There came a time when the risk to remain tight in the bud was more painful than the risk it took to blossom." Anais Nin

"Fear makes the wolf bigger than he is." German Proverb

Introduction

While there has been ample discussion of students at risk, mathematics education at risk, and nations at risk, there has been limited discussion of students willingness to take risks in mathematics and science education. Nonetheless, student-centered learning implies perceived risks by both students and teachers, who are asked to produce solutions to open-ended problems that by their nature have fuzzy criteria for correctness. It follows that individuals who have different perceptions of risk are more or less likely to do well in these environments. Appropriate educational environments must, therefore, take into account individual students and teachers risk-seeking or risk-averse attitudes.

The National Science Teacher Association (2003) describes inquiry according to Resnick (1987) as requiring "the use of nonalgorithmic and complex higher-order thinking skills to address open-ended problems. Multiple solutions may be possible, and the inquirer must use multiple, sometimes conflicting, criteria to evaluate his or her actions and findings. Inquiry is characterized by a degree of uncertainty about outcomes." Similarly, in mathematics education, Lave et al. (1988) suggests that " the goal would be to generate dilemmas, opportunities for invention, discovery, and understanding in patterns of activity, rather than to prescribe exercises on specific problem types and procedures." Taking these two perspectives as in some way representative of popular ideas in the educational community, the goals of contemporary mathematics and science education are very similar. Both propose the use of real-world problem-solving and inquiry-based educational environments that engage students in complicated problems with complex criteria for success. Both also involve risk and require participants to tolerate higher levels of confusion than are seen in more classical educational activities and direct instruction methods.

According to the work of Piaget, Dewey, Bruner and others, this confusion is seen as the mainspring of learning. Appropriate levels of internal conflict drive individuals to resolve that conflict with better solutions. Reimen (1999) puts it the following way with respect to teacher education, "Disequilibrium needs to be better understood as a central process in teacher development and teacher reflective activity. Substantial learning occurs in periods of conflict, confusion, surprise, and over long periods of time." Furthermore, Hubbard (2001) recognizes that tolerance for risk taking is critical to teacher change. In order for students to change, teachers must also change, and in both cases, change requires risk, but with constructivists approaches perceived risks are also generated in the achievement of the goal. However, the potential for adverse effects with students or teachers who do not appreciate the risks associated with constructivism suggests that the educational community must understand student and teacher tolerance for risk in order to create productive learning situations.

Tolerance for risk and confusion are directly related to students perceptions about their own goals. For example, there is ample evidence that individuals who differ in whether they are seeking mastery or performance goals also differ in their willingness to engage in challenging situations (Ames, et al., 1977; Dweck, 1986; Elliott & Dweck, 1988; Nicholls et al., 1985). Individuals who see learning as the ultimate goal and who are less worried about risks of assessment are more likely to pursue challenging material and thereby engage the risk and confusion associated with learning. However, when success is normatively defined, then both self worth and the perception of the material are at stake.

Ames & Archer (1988) observed that students willingness to take risks is associated with the student's perception of whether or not the classroom was focused on developing new skills (i.e., mastery goals) or on identifying ability and doing well on assessments (i.e., performance goals). "When students perceived emphasis on mastery goals, they reported using more learning strategies, preferred tasks that offered challenge, and had a more positive attitude toward their class" (Ames & Archer, 1988). In a given activity, students and teachers may perceive performance or mastery goals differently, and this may affect their willingness to participate or engage in 'risky' learning situations.

How teachers approach a curriculum may be a consequence of their perception of associated risks. According to the Burrills (1998) review of the Third International Mathematics and Science Study, 61% of lesson goals among United States teachers focused on skills, 22% focused on thinking, and 6% were on test preparation. Though many factors are undoubtedly involved in these decisions, the above evidence would suggest that students and teachers perceptions of risk associated with performance and the complexities associated with thinking are likely to be significant culprits. If students are unwilling to tackle challenging content with its associated risks of confusion and failure because of external performance evaluations, then these performance evaluations inhibit learning in the constructivist sense. With or without these performance evaluations, students and teachers are likely to show natural variation in their willingness to accept risks associated with thinking and this is likely to have long term consequences.

One aspect of this natural variation in response to risk is a tendency for females and males to respond to risk differently. In numerous areas, including financial decisions, health/safety, recreation, and ethical decisions, females are found to be more risk-averse than males (Weber et al., 2002). This perceived risk is also associated with alcohol and drug use (Spigner et al., 1993), environmental disasters (Flynn et al., 1994), and recreational activities (Boverie et al., 1995). Women also have less risky asset portfolios than men (Jianakoplos & Bernasek, 1998) and lower willingness to take financial risk (Powell & Ansic, 1998), and these behaviors may be related to lower risk taking in classrooms and pursuit of less challenging situations.

These gender differences in everyday decisions may also carry over to educational performance in mathematics. A meta-analysis performed by Hyde et al., (1990), assessing the performance of over 3,000,000 students, suggests that females outperform males in most grades, but that historically, this gender gap has been shrinking. However, they also note a significantly lower performance of females in mathematical problem-solving at the high school level. One can speculate about the sources of these problems, but students willingness to take risks associated with higher-level problem solving has not yet been evaluated.

If gender issues are prevalent in risk taking behavior then inquiry-based and student-centered learning opportunities may be inappropriately biased towards a specific gender. As well, if their is variation in risk-seeking or risk-averse behavior across students, then proposals to introduce risk-intensive curriculum must be appropriately guided to meet students at appropriate comfort levels. ADHD is a disorder strongly associated with risky behavior in the medical literature (Comings et al., 1999; Schinka et al., 2002). For contemporary educational practice to truly address learning disorders, it must understand how these disorders are manifested in the classroom and in what ways learning environments can be constructed to appeal to the learning strategies individuals bring to the classroom. As much of the variation in learning strategies goes unnoticed in standard direct-instruction, understanding what this variance looks like is of critical importance to the success of educational initiatives.

Finally, there is also a body of literature related to risk in animal behavior, (Bateson & Kacelnik, 1998). For example, the energy budget rule is a formal theoretical argument which suggests that animals should be risk averse unless they are in danger of having too little energy to survive, in which case they should be risk seeking (McNamara & Houston, 1992; Stephens, 1981). We use the risk terminology from this literature to dimensionalize risk in our evaluations of individual behavior (Figure 1). Though risk clearly has an effect on the lives of many people, be they subjects of biological experimentation or otherwise, it is unlikely that this important literature will be meaningful for education unless educational research works to expose risk tolerance in students and teachers.

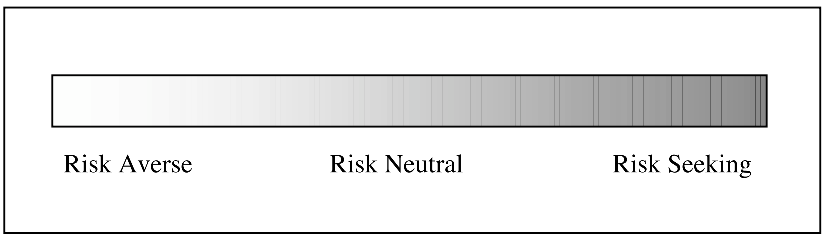

Figure 3: The Dimension of Risk. In various situations, students or teachers may be more or less likely to seek or accept risk. Students who are unwilling to operate autonomously and prefer instructions may be associated with risk aversion. Students who prefer to work on open-ended problems with limited guidance may be associated with risk seeking behavior.

The work presented here attempts to combine these threads through the use of an interactive computer simulation designed to engage students in a risky mathematical environment. Interactive computer simulations like NetLogo (Wilensky, 1999) allow teachers and researchers to record student's decisions in real-time. Through the use of a survey combining task preference questions from Ames & Archer (1988) and behavioral economics evaluations of risk from Tversky & Kahneman (1992), along with a data blind evaluation of student participation, we attempted to evaluate the relationship between risky behavior, participation, preference, and efficacy, and also to address questions of gender and the independence of mathematics and scientific risk taking.

Methods

Data was collected from two classes of pre-service teachers at the University of Texas at Austin. Approximately 30 students were involved, though because the simulation and survey took place on different days, some students were not present for one or the other. 32 students participated in the investing simulation, 33 students were evaluated for their participation during class, and 32 students filled out the five question survey. In cases were combinations of these data are compared, numbers may be lower.

The Investment Simulation

Pre-service teachers in both classes participated in an interactive investment simulation in which the goal was to own the most cars on the last turn. All students began with $100 at the beginning of the simulation and could choose to purchase cars at the price of $50 each at any time during the game. Students chose how much of the remainder to invest at each turn and received 30% return on their investment at the beginning of the next turn. Personal client monitors on student's laptops allowed individuals to follow their own bank accounts and number of cars purchased.

Before the first run of the game, students were allowed to play with the interface for a few turns until they all felt comfortable with the interface. Since the instructor could monitor the student's actions on an upfront monitor, the instructor could verify that students understood how to invest and buy cars simply by asking them to do so and then watching how their bank account and number of cars changed.

For the first run of the game students were told they would have exactly 10 turns before the game was over. Students were allowed to ask questions and were assured that the price of cars would not change, that there were an unlimited supply of cars, and that the interest rate would not change during the game. The optimal strategy in this situation is to invest all the money until the last turn and then to buy cars with the money. All students were observed to do this after the first few turns.

For the second run, students were told that after each turn the game would stop with a one in ten chance controlled by a randomly generated outcome button pressed by the instructor. In other words, the average game should last ten turns, but no one, not even the instructor, would know exactly when the game would stop. The optimal strategy during this part of the game is to play a mixed strategy, sometimes buying cars and sometimes not, or roughly spending an average of 1/3 of ones income each turn. This part of the game was played several times. In both classes, the first run with variable turn length lasted only a few turns (< 5). However, the second run lasted over 20 turns and data taken during this longer duration run are those used in the analyses that follow. We chose to use this run only because we felt it captured students initial inclinations in the game, unfettered by the opinions of other students or the instructor about how the game *should* be played.

Data were captured by recording each individuals decisions after each turn using the Hubnet NetLogo software command "export-world." This effectively saves all information presently in use during the simulation and is an effective way to follow student's decision in any NetLogo simulation. To reconstruct the game play, the "import-world" command is used, which restores the simulation to its form at the time the “export-world” command was given. Using the “import-world” command with consecutive save files, all decisions made over the course of the simulation were collected.

We evaluated several possible risk metrics and found three to be most effectively associated with preferences, participation, and efficacy. These were percentage of turns spent buying cars, standard deviation in number of cars purchased, and the length of turns the student initially went without purchasing a car. The standard deviation in number or cars purchased and the length of turns until first purchase were both split into two groups (split at 1.07 for standard deviation and greater than 3 turns till first purchase for length of initial investing streak). This was statistically necessary because some students who bought many cars but only infrequently or who waited for more than 17 turns to buy their first car created distributions with long upper tails, violating statistical prerequisites necessary for parametric statistics. By splitting the distributions into two groups, chi-square test then became an appropriate candidate for statistical evaluations. The risk metrics are not independent, nor could they be, as they are all taken from the same game. Our purpose in presenting all of them is to give readers a more accurate representation how risk in the game was correlated with other factors under study.

Fringe buying behavior (either too much or too little buying) turned out to represent two different risk groups, as determined by the survey and participation evaluation. This is discussed further below.

Survey of Risk Preference

Students were given a questionnaire to assess their preferences for mathematical or scientific risk or for challenging tasks. The questionnaire is shown in figure 1.

Your user id name used in the simulations:_______________

Please answer the following questions. Circle one answer per question.

1. On a 5-point scale (1 = not likely at all; 5 = very likely) indicate your preference for the following two types of projects:

__ A. a project where you can learn a lot of new things but will also have some difficulty and make many mistakes.

__ B. A Project that would have a minimum of struggle or confusion and you would probably do very well.

2. If given the opportunity to win $100 with a chance of 10%, or to be given $10 right now, I would...

A. Choose the $100, 10% of the time option.

B. Take the $10.

3. Most often, I prefer science activities with...

A. Open-ended outcomes that require innovative thinking and could easily amount to nothing or go far afield of the key scientific ideas.

B. Single correct answers, which require the ability to follow directions, and which demonstrate key ideas in science.

4. Compared to my peers, I see myself as _______ at mathematics.

A. Good   B. Okay   C. Poor

5. Most often, I prefer mathematics problems that...

A. Have one correct answer that is not difficult to find.

B. Don't have one correct answer, require creative thinking, and may not ever be solved satisfactorily.

Figure 1: The questionnaire given to all participants

Question one was taken from a survey given by Ames & Archer (1988), used to assess student's "task preference." Ames & Archer (1988) found that this question was positively correlated with student's perception of mastery goals in the classroom, willingness to try different learning strategies, and a positive attitude towards the class. Like Ames & Archer (1988), we took the larger valued of the two answers to represent the student's preference for risky tasks (A > B) or for non-risky tasks (B > A). Students who showed indifference to tasks (A = B) were not included in tests involving task preference. We use this question as control for question 5, which is focused on pre-service teachers preference for challenging mathematics problems. Question 2 is borrowed from the behavioral economics literature of Tversky & Kahneman (1992). Question 3 is used to assess students preference for open-ended science activities. And question 4 is used to assess students self-efficacy with respect to mathematics performance. Students were given the survey several days after the investment simulation.

Evaluation of Participation in Class Discussions

To evaluate participation in class discussions, the instructor and a teaching assistant both assigned scores of 1, 2, or 3 to all students, where 1 represented only speaking when spoken to, 3 represented active involvement in all open discussions, and 2 represented a position in between. Students were then assigned to two groups based on the combination of the two scores. One group represented those who participated infrequently (with scores of 1-1 or 1-2) and those who participated frequently (with scores of 2-3 or 3-3). It was intended that if both teaching assistant and instructor chose 2-2, then they would both be further queried to ask if they felt the student belonged in either group more than the other. This did not happen, however, as all students fell into two groups based on the initial evaluations. Summing over both classes, 12 students participated without being directly asked, 21 only participated in discussions when directly responding to a question by the instructor.

Results

Risky Behavior and the Investing Game

The main hypothesis associated with the investment game behavior is that risky behavior i the game will be indicative of student's risk preference in other areas of mathematics and science and their willingness to actively participate in class discussions. There are multiple ways to assess risk and we settled on three possible risk measures, including percentage of turns buying cars, variance in number of cars purchased, and longest run of turns without a car purchase. In all results reported, if a statistical relationship is not stated between one of these risk factors and another aspect of our inquiry, then the compared results were $p > 0.2$.

It is important to note that one of our initially proposed risk factors was whether or not students purchased cars too frequently or too infrequently. In other words, purchasing cars too frequently represents a kind of conservative risk, or gamble, that the game will end soon and so therefore it is best not to be caught empty handed. Purchasing cars too infrequently is playing on the risk that the game will not end soon and that more money can be invested to purchase more cars later. These risk groups represent the opposite tails of the "percentage of turns spent buying cars" distribution. However, this risk metric was not correlated with any other data metrics. On the contrary, the two tails of the distribution represented incompatible risk groups, with one end preferring risky open-ended mathematics, and the other end preferring easy mathematics with single correct answers. These results and others are shared below, and the topic is reconsidered in the discussion.

The major finding from the investing game are as follows:

1. **Percentage of turns buying cars was inversely correlated with risky task preference in the Ames & Archer question (1988) (Figure 2).**

The Ames and Archer (1988) question represents task preference and was shown by them to be correlated with other factors in students motivation to participate in challenging situations. The observation that students who purchase cars less frequently are more inclined to choose risky tasks is suggestive that risky game behavior is an indicator of engagement in risky tasks.

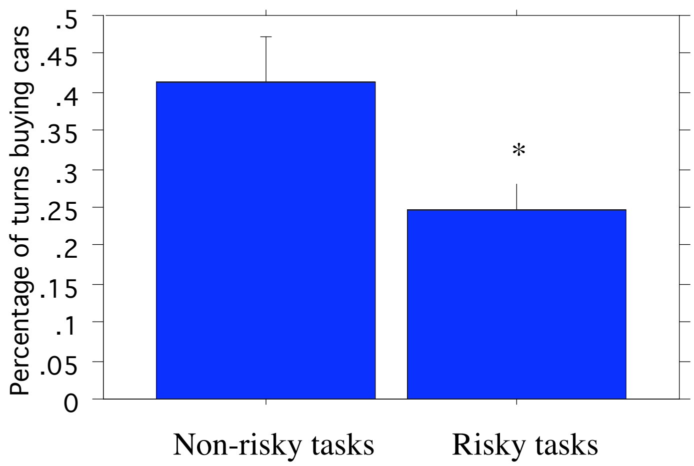

Figure 2. Percentage of turns where cars were purchased is strongly correlated with preference for risky tasks in the Ames & Archer question (* p-value = 0.041, students t-test).

2. **Teachers who took longer to make their first purchase also showed a preference for risky tasks in the Ames & Archer question (Table 1).**

Taking longer to make the first purchase is representative of a risk associated with holding out for higher profits by investing for longer. The majority of students purchased cars in the first three turns. Roughly three-quarters of these early buyers also preferred non-risky tasks, associated with limited challenge.

	Task Preference	
	Risky	Non-risky
Teachers who took < 4 turns to purchase	4	12
Teachers who took > 3 turns to purchase	8	4

Table 1: Results for comparison of in class discussion activity with preference for open-ended mathematics problems. (Chi-square p-value = 0.028). Students who showed indifference to task preference (Risky = Non-risky, or A=B) were not included in tests of task preference (see Methods).

3. **Active participation in class discussions was strongly correlated with high variance in number of cars purchased (Table 2) and longer durations taken to purchase first cars (Table 3).**

The previous two results showed that the our risk indicators in the game were associated with risk as measured in other studies. The data presented here show that one of the metrics, number of turns to before first car purchase, is also statistically correlated with active participation in class. As well, another risk metric we calculated, the standard deviation in number of cars purchased, was also statistically correlated with active participation. Because percentage of turns buying cars does not indicate how many cars were purchased, the standard deviation metric is a better indicator of binge buying.

That the two risk metrics are strongly correlated with active participation in class is highly suggestive of an association between risk tolerance and willingness to engage in constructivist approaches to learning. Few would argue that one of the standards of a constructivist approach to learning in the classroom is active discussion, either in groups or as class.

		Discussion Participation	
		Active	Passive
Standard devaition in	High	10	8
cars purchased	Low	2	13

Table 2: Results for comparison of involvement in class discussion and variance in number of cars purchased. (Chi-square p-value = 0.012).

	Discussion Participation	
	Active	Passive
Teachers who took < 4 turns to purchase	4	14
Teachers who took > 3 turns to purchase	8	7

Table 3: Results for comparison of in class discussion activity with preference for open-ended mathematics problems. (Chi-square p-value = 0.028).

4. **Teachers who preferred open-ended mathematics questions showed a trend towards purchasing cars less frequently in the game (Figure 3), purchased cars with higher standard deviations (p = 0.12, data not shown) and took longer to make their first purchase (p = 0.16, data not shown).**

These data were not significant according to our statistical measures (student t-tests and chi-squared tests). However, the trend associated with this data is clear and consistent with our previous findings for the Ames & Archer (1988) question. It is possible that our question (Question 5) is not a reliable measure of student's preference for challenging mathematics, despite its appearance.

Nonetheless, if the trend is to be trusted, then again we see evidence that risky behavior is associated with risky preference.

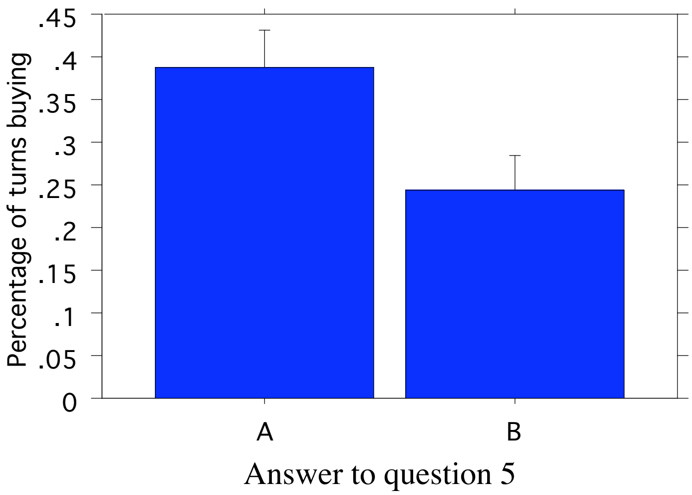

Figure 3: Percentage of turns student purchased cars compared between those selecting the different answers in question 5, preference for hard, open-ended versus easy, one-answer mathematics problems (p = 0.11).

5. **Teachers who showed more variance in car purchases preferred more open-ended science activities.**

This result again supports our main hypothesis, that risky behavior in the game is correlated with risk preferences in general. Here student's preference for science activities that might be associated with a constructivist approach to education are shown to correlate with binge buying in the game.

		Science Preference (Q. 3)	
		A	B
Standard deviation in	High	11	6
cars purchased	Low	4	10

Table 3: Results for comparison of standard deviation in car purchases with answers to question 3, regarding science activity preference (p= 0.045).

Class Participation

We were also interested in knowing how class participation in discussions was associated with student's tolerance for risk, task preference, and interest in challenging mathematics or science activities.

Here again, there are multiple ways to evaluate participation, and different environments often elicit the participation of different individuals. In the present case, since the classroom under study typically engaged in discussions regarding the content, we believed that the most robust assessment of participation would come by asking the instructor and teaching assistant to evaluate students based on whether they were active or passive participants. Active participants raised hands and had something to offer almost any discussion. Passive participants were unlikely to ever raise hands and only offered their opinions when specifically addressed. The absolute values of these two types are likely to differ for any given class, but in the present situation 12 of the 33 students evaluated were active participants. Not all of these students took the survey.

6. Students who passively participated in discussions preferred easier and more straightforward mathematics problems (Table 5).

Students who passively participate in discussions showed a strong preference for mathematics problems with "one correct answer that is not difficult to find" over problems that required "creative thinking, and may not ever be solved satisfactorily." Of those who only passively participated in discussions, 86% of students preferred less challenging mathematics. Of those who participated actively in discussions, there was no clear bias towards challenging mathematics. This result is indicative of one of the lessons in the study overall, which is that active participants in discussions are not a homogenous group of risk takers who prefer risk in all situations. Passive participants tend to share preferences with respect to risky mathematics, but are not as unilaterally risk-averse in other situations. Mathematics risk may be perceived as more risky than other kinds of risk. While risk does appear to be conserved across many tasks on average, there does appear to be individual variation even in our various risk groups.

		Math Preference (Q. 5)	
		A	B
Discussion	Passive	18	3
Participation	Active	6	7

Table 5: Comparison of student's participation in discussion with their preference for mathematics ($p < 0.014$).

7. Participation in class discussions was correlated with task preference according to the Ames & Archer (1988) question (Table 6).

Participation in class discussions is statistically correlated with preference for risky tasks. Passive participants preferred non-risky tasks and active participants preferred risky tasks.

		Task Preference (Q. 1)	
		Non-risky	Risk
Discussion	Passive	14	6
Participation	Active	3	7

Table 6: Comparison of student's participation in discussion with their task preference as per the Ames & Archer question (1988) ($p = 0.037$).

8. **Neither participation in discussions (p = 0.72) nor behavior in the investment game (standard deviation of cars purchased, p=0.62; percentage of turns purchasing, p=0.24; number of turns to first purchase, p = 0.62) was correlated with mathematics self-efficacy (data not shown).**

One of our hypotheses was that mathematics self-efficacy would be associated with other factors in how pre-service teachers handled or preferred risk in the classroom. We also suspected that this would be associated with willingness to participate in discussions. This was not supported by the data. Given the number of metrics we used to evaluate risk, it is unlikely that our metrics missed risk tolerance in the teachers. However, it is possible that our metric for mathematics self-efficacy lacks sensitivity. In our survey, 14 teachers saw themselves as "Good" as mathematics compared with their peers, while 17 claimed they were only "Okay." None claimed they were "Poor" at mathematics. Following our study, we feel that the question is probably not an accurate measure of student's efficacy with respect to mathematics.

If the question is an accurate measure of efficacy, then it suggests that students' evaluations of their own mathematics is independent of the kinds of risks they prefer or take in educational settings. It may be that individuals who take risks are more likely to value the mathematics they construct in those environments while those who avoid risks value their ability to solve less risky problems. In which case, mathematics efficacy may be difficult to evaluate with respect to risk tolerance.

Gender

Given the considerable data on differences in risk tolerance associated with gender, we hypothesized that we would observe gender differences among pre-service teachers willingness to engage in risky game behavior, class participation, or preference.

9. **Gender was not correlated with math preference (Q.5, p=0.86), math self-efficacy (Q.4, p = 0.62), or the Ames & Archer (1988) question (Q.1, p = 0.44, data not shown).**

This was a surprising result but given the quantity of risk metrics and their apparent correlation with one another, it is difficult to dismiss this result as an artifact. If anything, it may be evidence that pre-service teachers are not a random cross section of those who often wind up in studies of risk tolerance across genders.

10. **Males preferred open-ended science activities more than females (Table 7).**

Males preferred open-ended science activities while females preferred science activities that were more straightforward, required following directions well, and demonstrated key ideas in science. This may be evidence that there is a gender difference among pre-service teachers perceptions about the dynamic nature of science, or it may reflect genuine preference for less risky activities that may not turn out well. Given the lack of a gender bias in other risk metrics, it may that the question does not accurately measure risk preference in science activities. Only one of our game-based risk metrics was correlated with preference for open-ended science activities, so it is difficult to evaluate the true perceived risk associated with difference choices.

To the extent that the question does evaluate risk, the difference in gender preference is consistent with findings reported above that suggest that females are more risk averse than males.

		Gender	
		Male	Female
Science	A	11	4
Preference (Q. 3)	B	6	10

Table 7: Comparison of gender with preference for science activities as revealed by question 3 (p = 0.045).

Self-Efficacy

11. **Students who chose a sure gain over a low probability of a higher gain were also more likely to see themselves as poorer at mathematics than their peers (Table 8).**

The Tversky & Kahneman (1992) question was introduced to evaluate how our risk metrics compared with a classic question in behavioral economics. Our results show that more individuals prefer a certain small gain than a probabilistic larger one. However, that this question is not correlated with similar behaviors in the investment game suggests that this question is a less general measure of risk than the investment game.

During an in class discussion, one student reported that when he saw the question he didn't bother to do the calculation, and simply chose the sure gain. A reasonable interpretation of this result is that those who didn't trust their own ability to evaluate the probabilistic choice didn't make that choice. The simplicity of the mathematics makes this a painful interpretation. Another interpretation is that individuals who are good at math are more likely to take probabilistic risks when those risks are easily evaluated.

		Math Self-Efficacy	
		Good	Okay
Preference for	$10	5	14
	$100, 10% of time	9	5

Table 8: Comparision of response to gambling like question borrowed from Tversky & Kahneman (1992) and students perception of their own math skills as compared with their peers (p = 0.029).

Task Preference & Math & Science Preference

As a control for our measures of math and science preference and our metrics for risk in the investment game, we introduced the Ames & Archer (1988) question which has been shown to be correlated with students' preference for challenging questions and willingness to use alternate learning strategies.

12. Task preference was correlated with their mathematics preference.

Task preference is statistically correlated with mathematics preference. This is consistent with our previous results, showing that there are general risk metrics that are conserved across behavior and preference.

		Task Preference	
		Comfort	Risk
Math	A	14	6
Preference	B	3	7

Table 6: Comparison of teacher's math preference with their task preference as per the Ames & Archer question (1988) ($p = 0.045$).

13. Science preference was not correlate with task preference ($p = 0.30$) or math preference ($p = 0.16$, data not shown).

Science preference was no statistically correlated with most of our other metrics. The two alternative explanations for this are that this question fails to accurately measure risk associated with science activities, or that science activities are perceived as a different kind of risk than that shown to be cross correlated for most of our other risk metrics.

Discussion

Risk is ever present in our actions and our perceptions. Factors involved in our perception of risk are likely to have strong influences on our willingness to perform certain activities. This is especially true when those activities invite confusion, possibility of failure, and self-accountability, where one must make decisions for oneself. Given that these are, in part, central tenets of a constructivist approach to education, it is worth investigating how students perception of risk is or is not associated with their willingness to engage in constructivist activities in the classroom.

Our evaluations of risk used multiple metrics to address the many different ways that risk can be perceived in the classroom. A summary of our results is depicted in Figure 4. From a gross perspective, the results suggest numerous relationships between risky behavior, participation, and preference for constructivist science or mathematics. Overwhelming, risky behavior, participation, and preference for constructivist mathematics are strongly correlated. Those students who took longer to purchase cars, purchased cars less frequently, and purchased cars with the highest variance (i.e., in buying binges), also tended to be students who actively participated in class discussions, preferred challenging tasks in the Ames & Archer (1988) question , and preferred constructivist science activities. Active participation in class discussions was also strongly correlated with a preference for constructivist mathematics.

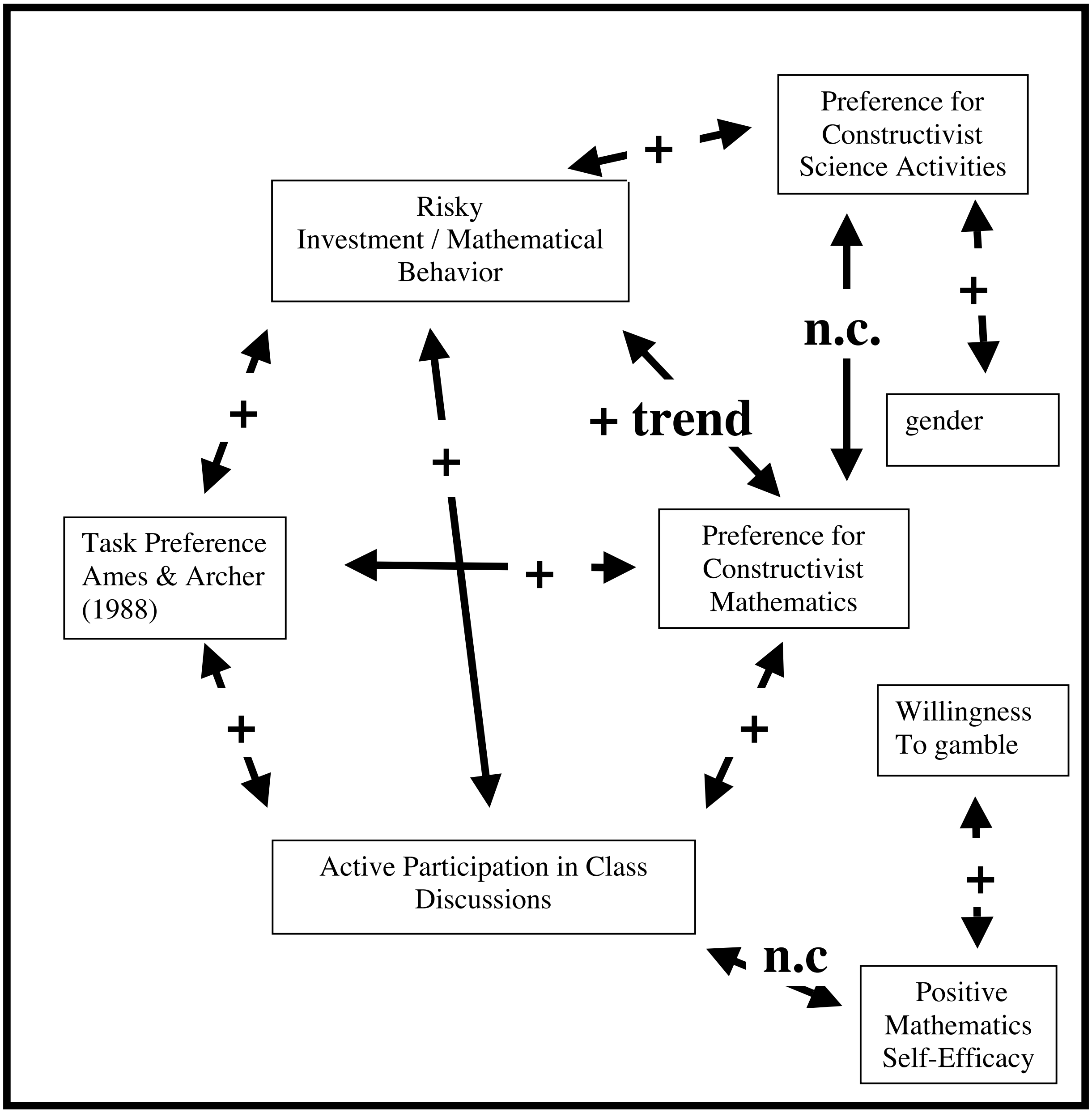

Figure 4: A visual representation of the correlations observed in this study. All risk behaviors from the investment simulation are represented by the composite "Risky Investment/Mathematical Behavior" and significant correlations with any of our three risk metrics for this game are depicted as evidence of a significant relationship in the figure. Significant positive relationships are depicted by a "+" and relationships where

results were not significant are depicted by an "n.c." for no correlation. Task Preference refers to Question 1 from the survey. Preference for constuctivist mathematics refers to question 5. Preference for constructivist science activities refers to question 3. Willingness to gamble refers to question 2. Positive mathematics self-efficacy refers to question 4.

Gender appears to play a small role in teacher preference and this may be more evidence that gender is playing less and less of a role in math and science proficiency in contemporary education (see Hyde et al., 1990). Our metric for willingness to gamble from Tversky and Kahneman (1992) also appears to be a poor measure of students' willingness to take risks in other activities. Curiously, however, it may be an instrument for evaluating self-efficacy. The lack of positive correlations in other areas may suggest that this result is not as robust as the others and should be regarded with caution until investigated more thoroughly.

Not all of the results are straightforward. The observation that risky behavior in the game is not a significant indicator of risky mathematics preference, but that risky behavior is significantly associated with active participation and risky task preference, which are correlated with math preference, is at first somewhat enigmatic. Numerically, the explanation is that most individuals do not show the same constellation of preferences. Individuals who prefer constructivist mathematics problems are not likely to necessarily play the game in a more risky fashion. Discussion with students following the survey suggested that some of those who prefer constructivist type mathematics activities, also thought deeply about what the optimal strategy was during the game and played accordingly. Optimality seeking behavior could easily be interpreted as conservative or risk-averse, since the goal is not to gamble, but to minimize risk associated with too severely challenging the odds. Meanwhile, a few students, who showed clear preferences for non-risky tasks or mathematics and who participated infrequently, were wildly risky in the game.

These intermediate individuals appear to be those who have developed mixed risk strategies in their educational behavior, and this may account somewhat for their educational persistence. It is easy to see how individuals who are too risk-seeking or too risk-averse may have difficulty functioning in classrooms. However, if they moderate their approach to risk by behaving antithetically to their typical risk preferences in certain situations, they may play the odds in classrooms in the same way that individuals could choose different strategies in the game, but still be purchasing cars approximately 33% of the time. Some may purchase many cars infrequently, while others purchase few cars often.

Another curious result is that individuals who showed the highest percentage of car purchases also tended to prefer less risky mathematics and tasks (Figure 3). Curiously, of those individuals who purchased cars most frequently, they were unilaterally risk-averse in all other situations (Figure 4 shows this for the Ames & Archer question). From a mathematical definition of risk, it does not follow that these individuals are risk-averse. These individuals are purchasing cars too frequently and are therefore gambling that the game will end sooner than it should on average. One explanation for this is that frequent purchasers don't want to be left without any cars when the game is over—they are willing to risk low to moderate performance for a clear loss. Four of the five individuals in the bottom right hand corner of Figure 5 also chose $10 over $100, 10% of the time. For them, the risk is not associated with failing to win, but with losing. The preference for winning or not losing is an important one that this study was not designed to test, but the question is open and the results here suggest that the results are likely to be meaningful with respect to learning related risks.

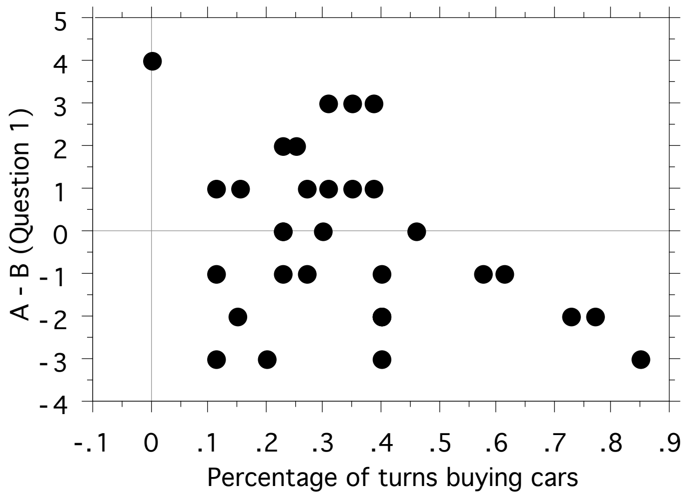

Figure 5: Comparison of individuals purchasing frequency with their preference for risk in the Ames & Archer question. Black circles represent individuals. The five individuals on the bottom right are risk-averse in all situations.

Our results suggest that risky game behavior, participation , and preference are factors at work in the successful operation of a constructivist approach to learning. While we found that these factors were all positively correlated, we did not however find a relationship with mathematics self-efficacy (except in the Tversky and Kahneman question), nor did there appear to be a relationship with gender (except in the science activity question). The observation that game behavior, participation, and preference are all related suggests that classrooms that too strongly approach constructivist mathematics with open-ended questions that create confusion (i.e., disequilibrium) and challenge students with the risk of failure, may not be perceived as fruitful, or even educational, for many of the students who do not share the same risk tolerance as the teacher.

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