JOURNAL OF RESEARCH IN SCIENCE TEACHING VOL. 46, NO. 2, PP. 210–223 (2009)

Correlates of Intellectual Risk Taking in Elementary School Science

Ronald A. Beghetto

College of Education, 5277 University of Oregon, Eugene, Oregon 97403-5277

Received 9 May 2007; Accepted 9 May 2008

Abstract: This study had the goal of exploring factors associated with elementary students' ($N = 585$) reports of intellectual risk taking in science. Intellectual risk taking (IRT) was defined as engaging in adaptive learning behaviors (sharing tentative ideas, asking questions, attempting to do and learn new things) that placed the learner at risk of making mistakes or appearing less competent than others. Results of hierarchical regression indicate that students' reports of IRT declined by grade-level, but were positively related to interest in science, creative self-efficacy, and perceptions of teacher support. Of all the factors considered, interest in science was found to have the strongest unique and positive relationship with students' reports of intellectual risk taking in science. © 2008 Wiley Periodicals, Inc. J Res Sci Teach 46: 210–223, 2009

Keywords: general science; student beliefs; values; attitudes; elementary

Helping students develop their ability to reason scientifically is a key goal of science education in the U.S. and abroad (Chinn & Malhotra, 2002; ICASE, 2003; National Research Council, 1996). An important attribute of scientific reasoning, given the uncertain nature of scientific inquiry, is the willingness to take risks. Every experiment runs the risk of failure and all scientific ideas face the possibility of being disconfirmed. Thus, helping students develop their ability to reason scientifically involves supporting their willingness to take risks in the form of sharing their tentative ideas, asking questions, trying-out new procedures and strategies, and subjecting their ideas and conceptions to disconfirming evidence (Bransford & Donovan, 2005).

Such behaviors are considered *risky* because there is ‘‘some chance that the action could produce undesirable consequence’’ (Byrnes, 1998, p. 142). For instance, although sharing one's ideas during a class discussion is an adaptive learning behavior (possibly leading to the development of more sound scientific conceptions); students may be reluctant to do so because of a fear that their ideas may be dismissed, discounted, or even ridiculed (‘‘If I share this idea everyone will laugh at me’’). Therefore, some adaptive learning behaviors (asking questions, sharing ideas, trying new things) are risky because of the possibility of undesirable consequences.

These risks constitute a special class of risk taking called *intellectual risk taking* (IRT). IRT is defined here as engaging in adaptive learning behaviors (sharing tentative ideas, asking questions, attempting to do and learn new things) that place the learner at risk of making mistakes or appearing less competent than others. This definition is based on prior descriptions of IRT (Byrnes, Miller, & Schafer, 1999; Clifford, 1991) and highlights the fact that learning (like most any action) involves uncertainty and, therefore, some degree of risk (Byrnes, 1998).

The aim of this study was to provide an initial examination of potential correlates of IRT in a sample of elementary science students. First, a brief review of research on IRT is provided. This is followed by a discussion of potential correlates of IRT. Next, the results of this study are reported. The article closes with a discussion of the results and offers implications for future research.

Correspondence to: R. A. Beghetto; E-mail: beghetto@uoregon.edu

DOI 10.1002/tea.20270

Published online 24 December 2008 in Wiley InterScience (www.interscience.wiley.com).

Intellectual Risk Taking

Intellectual risk taking, unlike other forms of risk-taking behavior (sky diving), is considered adaptive because the benefits of engaging in IRT are thought to outweigh the consequences. Prior research has linked IRT with student learning and academic identity development (Bransford & Donovan, 2005; Clifford, 1991; Clifford & Chou, 1991; Streitmatter, 1997). For instance, Streitmatter (1997) has reported that IRT (in the form of sharing one's tentative ideas during class discussions) helps to shape students' academic identity and, in turn, promotes academic achievement. Similarly, Clifford (1991), following Vygotsky's concept of Zone of Proximal Development, has explained that engaging in tasks just above one's current ability level is a form of IRT that promotes learning and cognitive development.

Although IRT is considered an adaptive form of risk taking, students' concerns about making mistakes and looking incompetent in front of others are very real (Dweck, 1999). These concerns seem to be most pronounced in school-based settings and on school-like tasks. Prior IRT research has demonstrated that students are more likely to take intellectual risks on game-like tasks as opposed to school-like tasks (Clifford, 1991; Harter, 1978). For instance, Clifford and Chou (1991) found that when Taiwanese fourth graders were prompted to believe that they were playing a game ("play a game to practice your thinking skills") versus demonstrating their ability on a school-like task ("take a test to show how good your thinking skills are"); students in the game-like conditions were significantly more likely to take intellectual risks by selecting more challenging mathematical and spatial reasoning tasks.

Given that previous research has indicated that students seem more reluctant to take intellectual risks on school-like tasks, there is a need to understand what factors might be related to students' willingness to engage in IRT while learning science. This is of particular importance to science educators given that IRT is a key attribute of scientific reasoning (Bransford & Donovan, 2005). At present, however, little is known regarding factors related to elementary science students' willingness to engage in IRT.

Prior IRT research is limited, generally focused on topics other than science, and mixed. For instance, whereas some researchers (Clifford, 1988; Clifford, Lan, Chou, & Qi, 1989) have found no gender differences in elementary and middle school students' IRT, others (Byrnes et al., 1999) have found that female students generally are less inclined to take intellectual risks. Similarly, findings pertaining to age related differences in IRT also are mixed. For instance, whereas researchers (Clifford, 1988; Clifford et al., 1989; Clifford, Chou, Mao, & Lan, 1990) consistently have found age-related declines in students' tolerance for failure (as measured by items such as, "I feel terrible when I make a mistake in school"), findings have been inconsistent pertaining to the relationship between student age and their selection of more risky (i.e., more challenging) academic reasoning tasks. For example, some studies (Clifford, 1988) have demonstrated age-related declines in IRT, other studies (Clifford et al., 1989) have shown evidence of age-related gains in IRT (when students were awarded more, rather than a fixed amount of, points for completing more challenging problems), and still other studies have demonstrated no age-related difference (Byrnes et al., 1999). Finally, whereas some studies have demonstrated that ability is a significant predictor of students' IRT (Clifford et al., 1990), others have painted a less clear picture. For example, Miller and Byrnes (1997) found that elementary and middle school students' math grades were uncorrelated with IRT in math; however, their self-perceived math ability was significantly correlated with IRT in math.

Given the limited and mixed findings of previous IRT research and the lack of IRT in science education, this study contributes to the science education literature by offering an initial probe into factors that may be related with elementary science students' willingness to engage in IRT. Specifically, this study had the goal of examining whether students' self-beliefs (i.e., interest in science, creative self-efficacy in science) and perceptions (i.e., perceptions of teacher support) were related to their reports of IRT (after controlling for science ability, gender, ethnicity, and grade-level). Also, because the elementary school years can have a formative and lasting influence on students' science beliefs, attitudes, and future career choices (Blatchford, 1992; Jarvis & Pell, 2005; Musgrove & Batcock, 1969; Woolnough, 1990), the results of this study may prove useful to science educators and researchers by suggesting starting points for further research aimed at understanding and cultivating IRT in students.

Potential Correlates of IRT

When considering factors that might be related to students' intellectual risk taking in science, researchers have a vast array to choose from, including (but not limited to): students' prior learning and schooling experiences (past histories and experiences with science learning), cultural influences (various patterns of participation in dynamic communities of practices; Gutiérrez & Rogoff, 2003), unique contextual influences (the specific nature of science learning activities, settings, and tasks), and students' personal beliefs and perceptions (students' beliefs about science, students' self-competence beliefs, and perceptions of teacher support). Presently, however, little is know regarding the relationships between any particular set of these factors and students' IRT in science education.

Prior theory and research on students' beliefs and perceptions offers a potentially fruitful starting point for exploring correlates of IRT in science education. For instance, prior theory and research on interest (Renninger, 2000), creative self-efficacy (Bandura, 1997; Beghetto, 2006) and perceptions of support (Nickerson, 1999) suggest that these factors are at least conceptually related with students' IRT in science education. These conceptual relationships, and the need for empirical exploration of these relationships, are highlighted in the sections that follow.

Interest in Science and IRT

Interest in science seems to be a key factor in understanding students' willingness to take intellectual risks when learning science. Scholars have distinguished between two forms of interest, *situational* interest and *individual* (sometimes called *personal*) interest (see Hidi, 2000; Renninger, 2000; Schiefele, 1991 for a review). Whereas situational interest refers to temporary (although, potentially enduring) interest, which is triggered by certain environmental conditions (a unique science demonstration); individual interest refers to enduring and evolving interest in some object or topic (a students' interest in science). Importantly, as Hidi and Renninger (2006) have pointed out, these two forms of interest are related and can be thought of as representing different phases of interest development (with situational interest representing an initial phase that, ultimately, can develop into well-formed individual interest).

Reviews of research on situational and individual interest (Hidi, 2000; Hidi & Renninger, 2006; Renninger, 2000) have documented that both situational and individual interest are associated with favorable learning behaviors (focusing of attention) and outcomes (enhanced levels of learning). However, when it comes to IRT, the relationship between interest and risk-taking may be a bit more nuanced (with individual interest being more influential than situational interest). For instance, Clifford and Chou (1991) found that although fourth grade students' situational interest (their interest in working on novel problem solving tasks) was significantly correlated with their tolerance for failure, situational interest was not a reliable predictor of students' choice to work on riskier mathematical and spatial reasoning tasks.

Such findings suggest that situational interest may not be enough to actually result in students' willingness to select more challenging tasks to complete. A more developed personal interest seems necessary for students to be willing to take intellectual risks. For instance, Renninger (2000) has explained that individuals with more developed interests (as compared to those with less developed interests) are more likely to ‘‘take risks and be resourceful’’ (p. 377). This willingness to take risks and demonstrate resourcefulness makes sense given that individual interest develops from repeated and deep levels of engagement with a topic and thereby results in more robust knowledge structures, higher value for the topic of interest, and a greater willingness to seek out and persist in the face of challenges (Hidi, 2000; Renninger, 2000).

Moreover, students with more developed interests may be more likely to take risks (as compared to students with less developed interests) because they feel compelled (and able) to take action on the objects of their interest. For instance, as Hunter and Csikszentmihalyi (2003) have explained:

> To experience interest, by definition, implies that one is interested in *something*. Interest does not occur without a referent, whether it might be the attractive person standing across the room from me, or the fascinating book on the bestseller list. This necessarily means that to facilitate experiencing interest I must grapple with my reality in a way that somehow affects it. This could be walking across the room to

> start up a conversation, or going to the library to borrow the desired book. Interest *requires* action. It follows then, that those who experience a great deal of interest in their lives would also likely believe they are the volitional force behind their actions (p. 33).

Given that students with more developed personal interests more frequently take action on their interests, and because most actions have uncertain outcomes (Byrnes, 1998), it seems likely that students with higher levels of personal interest in science would also be more willing to take intellectual risks when learning science. At this point, however, such an assertion requires empirical examination. Thus, this study endeavored to examine the potential relationship between IRT and interest in science (while also controlling for ability in science, student characteristics, creative self-efficacy in science, and perceptions of teacher support).

Creative Self-Efficacy and IRT

Creative self-efficacy refers to a self-judgment of one's imaginative ability and perceived competence in generating novel and adaptive ideas, solutions, and behaviors (Beghetto, 2006; Tierney & Farmer, 2002). Prior research has linked creative efficacy with a variety of positive beliefs and outcomes, including: students' motivational beliefs and academic aspirations (Beghetto, 2006), creativity ratings by supervisors (Tierney & Farmer, 2002), and students' perceived science competence (Beghetto, 2007a).

Given that IRT in science involves putting one's ideas and conceptions at risk of being disconfirmed, a strong self-belief in one's ability to generate new and adaptive ideas would seem to be linked with students' willingness to engaging in IRT in science education. As noted earlier, positive self-competence beliefs have been found to be strongly related to IRT, even more so than actual ability (Miller & Byrnes, 1997). Thus, with respect to IRT in science education, creative self-efficacy likely is associated with students' willingness to engage in IRT.

Previous research has demonstrated how self-efficacy beliefs help individuals frame risks (for instance, viewing a new situation as a challenging opportunity vs. a threat), the willingness to take risks, and exerting effort in the face of difficult odds (see Bandura, 1997 for a review). The link between creative self-efficacy and risk taking is also evidenced in the history of innovation:

> The history of innovation vividly documents that premature abandonment of advantageous ventures because of early failures and discouraging setbacks would have deprived societies of the major advances they enjoy in virtually every aspect of life. It was Edison's unshakeable belief in his *inventive efficacy* that illuminated our environment and spawned the recording and movie industries, just to mention a few of his wondrous creations (Bandura, 1997, p. 456, emphasis added).

Given the seemingly important role that efficacy beliefs play in determining whether students will engage in IRT, it seems likely that a link will exists between students' creative self-efficacy and IRT in science education. At this point, however, the link between elementary students' creative self-efficacy and their IRT in science education remains speculative. As such, this study also endeavored to examine this potential relationship (while also controlling for science ability, personal characteristics, interest in science, and perceptions of teacher support).

Perceptions of Teacher Support and IRT

Examining whether a relationship exists between students' perceptions of teacher support and their reports of IRT may also yield important insights. Prior scholarship has highlighted the link between students' positive perceptions of the learning environment and their motivational beliefs in general (Alonso-Tapia & Pardo, 2006) and their willingness to take intellectual risks in particular (Nickerson, 1999). For instance, with respect to IRT in math, Kalchman and Koedinger (2005) have argued that IRT can be encouraged by ''creating a classroom atmosphere in which students feel comfortable to explore, experiment, and take risks in problem solving and learning'' (p. 373).

Students' perceptions of teacher support seem no less important when it comes to IRT in science education. For instance, Bransford and Donovan (2005) have reported that teachers in successful science classrooms cultivate "a culture of respect, questioning, and risk taking" (p. 415). Students' willingness to take intellectual risks in such classrooms seems, as Bransford and Donovan (2005) have noted, to be encouraged by teachers who encourage "a diverse array of thoughts about issues and phenomena" (p. 415). By doing so, teachers help students recognize that uncertainty and multiple perspectives signify engagement in "authentic scientific inquiry" (Chinn & Malhotra, 2002) as opposed to "a failure to converge immediately on 'the right answer' " (Bransford & Donovan, 2005, p. 415).

This type of classroom culture, which encourages intellectual risk-taking, is starkly different from prototypical classrooms in which unexpected student ideas are "habitually dismissed" (Kennedy, 2005). Dismissive science learning environments can result from a variety of factors, including: teachers (tacitly) discouraging students' expression of ideas by failing to take into consideration students' content-related experiences and prior knowledge (von Aufschnaiter, Erduran, Osborne, & Simon, 2008), an over-reliance on authoritative (as opposed to dialogic) discourse during teacher-student interactions (Chin, 2007); and non-responsive teaching and assessment practices (underwritten by limited views of students' prior knowledge) that have carried over from prospective teachers' own prior learning experiences (Otero & Nathan, 2008).

When teachers dismiss, ignore, or otherwise do not encourage students' tentative ideas, students quickly learn that it is not worth the risk to share potentially unexpected ideas—"even if they seem relevant and important to students" (Kennedy, 2005, p. 120). IRT in science education therefore seems to be encouraged when students' perceive their teachers as welcoming tentative ideas and demonstrating a commitment to "listen respectfully to what they say" (Minstrell & Kraus, 2005, p. 476). In addition, students' willingness to take intellectual risks also seems contingent upon receiving, when appropriate, positive competence related feedback. Teachers play a key role boosting students self-competence beliefs by providing students with positive (and believable) competence-related feedback (Bandura, 1997) which, in turn, is related to students' willingness to take intellectual risks (Miller & Byrnes, 1997). As such, it can be asserted that students who perceive their teachers as providing support in the form of listening to their ideas and offering favorable competence-related feedback would be more likely to take risks in their science learning (as compared to those who have not received such support). This study endeavored to examine this assertion.

Research Questions

The following research questions guided the investigation: What personal characteristics (gender, ethnicity, grade-level, and science ability) might be associated with students' reports of IRT? After controlling for differences in gender, ethnicity, grade-level, and science ability; how might students' willingness to engage in IRT be related to their interest in science? Also, because IRT involves putting one's ideas at risk of being disconfirmed, how might IRT be related to students' creative self-efficacy beliefs? Finally, how might students' perceptions of the teacher support (in the form of listening and providing competence related feedback) be related to their willingness to take intellectual risks?

Method

Participants

The 585[1] participants were students from seven elementary schools located on the coast of the Pacific Northwest. Students were enrolled in grades three through six. Students reported their ethnicity as White ($n = 442$, 76%), Native American ($n = 55$, 9%), Hispanic/Latino ($n = 40$, 7%), Asian/Pacific Islander ($n = 14$, 2%), African American ($n = 3$, 0.5%), or Other ($n = 31$, 5.3%). Slightly over half of the participants reported their gender as female ($n = 299$, 51%).

Instruments and Procedures

Data used in this study were drawn from data collected as part of larger project focused on supporting science teaching and learning in coastal elementary schools. Data used in this study were collected from two data sources: (1) a paper-and-pencil student survey; and (2) teacher-ratings of students' science ability. Graduate teaching fellows assisted in the administration of student surveys in the late spring of 2006.

The student survey included four items that asked students to report their age, gender, ethnicity, and grade level. Likert-type items ranging from 1 (*not true*) to 5 (*very true*) were used to measure students' intellectual risk taking, interest in science, creative self-efficacy in science, and perceptions of teacher support. Teachers ratings of student science ability were drawn from a rating sheet that asked teachers to rate each of their students (using other students in the class as a comparison) on *demonstrated science understanding* (i.e., student understanding demonstrated in all science discussions, activities, and assessments). Teachers rated each of their students for two time periods (fall of the academic school year and late spring of the academic school year) on a five point rating scale (1 = lowest, 3 = average, 5 = highest). Teachers' fall and spring ratings of students were significantly correlated ($r = 0.62, p < 0.001$) and therefore combined to form an averaged measure of student science ability.

Intellectual Risk Taking. Six items were used to assess students' intellectual risk taking in science ($\alpha = 0.80$). The items were developed from definitions and descriptions of IRT (Byrnes, 1998; Byrnes et al., 1999; Clifford, 1991; Streitmatter, 1997). Specifically, items were intended to measure students' reports of engaging in intellectually risky learning behaviors (sharing tentative ideas, asking questions, willingness to try and learn new things) when learning science. Items measuring students' reports of IRT are listed in Appendix.

Interest in Science. Four items were used to measure students' individual interest in science. The items were written based on Schiefele's (1991) definition of personal interest and therefore included content-specific *feeling-related* (I like science) and *value-related* (Science is important to me) components. The four items used to assess personal interest in science demonstrated acceptable levels of internal consistency ($\alpha = 0.77$) and are listed in Appendix.

Creative Self-Efficacy. Five items were used to assess students' creative self-efficacy in science ($\alpha = 0.83$). The items were intended to assess students' beliefs about their ability to generate novel and useful ideas in science and whether they viewed themselves as having a good imagination in science. The items were written based on previous descriptions and measures of creative self-efficacy (Beghetto, 2006; Tierney & Farmer, 2002) and modified for this study to assess creative self-efficacy in science. The five creative self-efficacy items used in this study are listed in Appendix.

Perceptions of Teacher Support. Three items were used to measure students' perceptions of teacher support ($\alpha = 0.77$). The items were written to assess key aspects of teacher support highlighted in the research literature (Bandura, 1997; Minstrell & Kraus, 2005; Nickerson, 1999) and thought to be associated with IRT in science education. The three items used to assess perceptions of teacher support in this study are listed in Appendix.

Creation of Construct Scores. Item-level principal axis factor analysis, with Promax rotation and k value of 4 (Tataryn, Wood, & Gorsuch, 1999), was used to examine the factor structure of the items used in this analysis. Four interpretable factors were extracted[2] which accounted for 49.5% of the Variance. The factor loadings are reported in Appendix. Construct scores were created from calculating mean ratings for items making up each of the four constructs (*Intellectual risk taking*, *Creative self-efficacy*, *Interest in science*, and *Perceptions of teacher support*).

Results

Descriptive statistics and zero-order correlations are presented in Table 1. As illustrated in Table 1, students, on average, reported that they were willing to take intellectual risks in science. In addition, a positive relationship was found among intellectual risk-taking, science ability, personal interest in science, creative self-efficacy in science, and perceptions of teacher support.

Hierarchical regression analysis was used to simultaneously examine the relationship between students' reports of IRT in science education and students' characteristics (gender, grade, and ethnicity), science ability, science interest, creative self-efficacy in science, and perceptions of teacher support. The ordering of steps reflected the goals of the study. In the first step, student characteristics were entered. Student characteristics included: grade level (a continuous variable), dummy-coded variables representing gender (0 = male, 1 = female), ethnicity (0 = Anglo), and Teachers' ratings of student science ability (a continuous variable). In the second step, the relationship between IRT in science education and science interest and

Table 1
Means standard deviations, and Pearson correlations

Variable	M	SD	1	2	3	4	5
(1) Intellectual risk taking	3.73	0.84	—	0.16	0.57	0.56	0.52
(2) Science ability	3.43	0.78		—	0.14	0.18	0.09
(3) Interest in science	3.62	0.87			—	0.51	0.42
(4) Creative self-efficacy in science	3.12	0.97				—	0.50
(5) Teacher support	3.34	1.08					—

Note: $N = 585$; All Pearson correlations were statistically significant, $p < 0.05$.

creative self-efficacy was examined (after controlling for student characteristics). In the third and final step, the relationship between intellectual risk taking and perceptions of teacher support was examined (after controlling for student characteristics, science interest, and creative self-efficacy). Results of the hierarchical regression are presented in Table 2.

Student Characteristics

Student characteristics, entered in step 1, explained a statistically significant amount of the variance (7%) in students' intellectual risk taking in science, $F(4, 580) = 11.45$, $p < 0.001$. Students' intellectual risk taking in science was negatively related to grade level ($\beta = -0.21$, $p < 0.001$) and positively related to science ability ($\beta = 0.16$, $p < 0.001$).

Science Interest and Creative Self-Efficacy

Results from step 2 revealed that including students' science interest and creative self-efficacy increased the amount of variance explained by 37%, $F\Delta(2, 578) = 193.61$, $p < 0.001$. Intellectual risk taking in science was positively related to students' science interest ($\beta = 0.38$, $p < 0.001$) and creative self-efficacy in science ($\beta = 0.35$, $p < 0.001$). Interestingly, science ability ($\beta = 0.04$, $p = 0.23$) was no longer statistically significant once science interest and creative self-efficacy beliefs were added in step 2 of the model.

Table 2
Summary of hierarchical regression analysis

Variables	Step 1			Step 2			Step 3		
	B	SE B	β	B	SE B	β	B	SE B	β
Student characteristics									
Grade	−0.19	0.04	−0.21**	−0.08	0.03	−0.09*	−0.07	0.03	−0.08*
Gender	0.06	0.07	0.04	0.13	0.05	0.07*	0.09	0.05	0.05
Ethnicity	−0.06	0.08	−0.03	−0.01	0.06	−0.01	−0.01	0.06	−0.01
Science ability	0.18	0.04	0.16**	0.04	0.03	0.04	0.05	0.03	0.04
Self-beliefs									
Interest in science				0.37	0.04	0.38**	0.32	0.04	0.33**
Creative self-efficacy				0.30	0.03	0.35**	0.23	0.03	0.27**
Perceptions of teacher support									
Listen and provide feedback							0.17	0.03	0.22**
R^2		0.07***			0.45***			0.48***	
ΔR^2					0.37***			0.03***	

Note: $N = 585$.
$^*p < 0.05$.
$^{**}p < 0.01$.
$^{***}p < 0.001$.

Perceptions of Teacher Support

Finally, results from step 3 indicated that including students' perceptions of teacher support increased the amount of variance explained in intellectual risk taking by 3%, $F\Delta$ (1, 577) = 38.19, $p < 0.001$. Intellectual risk taking, in step 3, was positively related to students' perceptions of teacher support ($\beta = 0.22$, $p < 0.001$). After controlling for all other variables, the strongest relationship existed between students' interest in science and intellectual risk-taking in science.

Discussion

This study had the purpose of exploring factors associated with elementary science students' willingness to engage in IRT. With respect to student characteristics, results of this study indicate that older students were less willing to engage in IRT (even after controlling for ability, self-beliefs, and perceptions of teachers). This finding offers new, subject-specific insights into previous research that consistently has found age-related declines in students' general tolerance for failure (Clifford, 1988; Clifford et al., 1989, 1990).

Although scholars (Clifford, 1991; Clifford & Chou, 1991) have offered potential explanations for declines in students' tolerance for failure and risk-taking (more competitive grading policies, increased focus on social comparison, and pressure to produce "errorless learning" and "perfect papers"), there is a need to identify factors that might ameliorate such declines. The results of this study offer a hypothesis for how such declines might be ameliorated. Specifically, the results indicate that although IRT generally declined with age; students' science ability, interest, creative self-efficacy, and perceptions of teacher support may serve as a counter-balance to age-related declines in IRT. Although this ameliorative effect is speculative at this point, it provides researchers with an important avenue for subsequent inquiry.

With respect to ability, students with higher levels of science ability were significantly more like to engage in IRT (as compared to those with lower levels of science ability). Interesting, however, after including students' interest in science and creative self-efficacy beliefs in the regression model, the relationship between science ability and IRT was no longer significant. This finding mirrors previous IRT research (Miller & Byrnes, 1997), which has suggested positive self-beliefs may be even more important than ability when it comes to the willingness to engage in IRT. The results of this study indicate that students' interest in science, creative self-efficacy, and perceptions of teachers were uniquely and significantly related to their reports of IRT. These findings are discussed in the sections that follow.

Interest in Science and IRT

Results of this study provide correlational evidence in support of the assertion that interest in science is a key factor associated with students' willingness to engage in IRT. In fact, after controlling for all other variables in the regression model, interest in science accounted for the greatest proportion of variance in IRT scores. The link between science interest and the willingness to take intellectual risks in science aligns with previous research which has documented similar links between interest and persistence in the face of frustration and failure (Hidi, 2000; Renninger, 2000). Taken together, these findings suggest that more interested students are also more willing to take intellectual risks when learning and will have the "staying power" (Hunter & Csikszentmihalyi, 2003) necessary for working through frustrations, set-backs, and failures in pursuit of their interests. Conversely, less interested science students likely do not see the rewards of deeper levels of science understanding being worth the risk of failure and frustration that may result from sharing their ideas, asking questions, or trying new things when learning science.

The strong association found between science interest and students' willingness to engage in IRT warrants further inquiry. It will be important to examine what effect teachers have on students' IRT when they more directly focus their instructional efforts on sparking and sustaining student interest. Of course, sparking and sustaining student interest is easier said than done. Science educators, like most teachers, may not have a clear understanding of how they might go about supporting students' interest in science (Hidi & Renninger, 2006). In fact, Lipstein and Renninger (2007) have reported that teachers often believe that student interest is something that either is present or not in children and therefore may fail to recognize the role they play in supporting the development of student interest. Such problematic beliefs and limited understandings of how to support student interest may be responsible both for age-related declines in students' science interest and age-related declines in IRT.

Fortunately, recent research examining factors associated with students' interest in science (Basu & Barton, 2007) and recent models of how interest develops (Hidi & Renninger, 2006; Krapp, 2002, 2005) offer a potential curative for these problematic beliefs. Research on science interest and models of how students' interest develops highlight the central role that teachers play in creating learning environments that might trigger and support students' developing interests. Equipping teachers with strategies for sparking and supporting interest is particularly important for elementary science educators, as teacher support is critical during children's initial, school-based science learning experiences. As Hidi and Renninger (2006) have explained

> Because external support that is contextualized in content is particularly critical in the early phases of interest development, it is during the early phases of experience that educators are most able to help students feel positive about their emerging abilities to work with content. . .positive feelings for content may be facilitated by offering choice in tasks. . .promoting a sense of autonomy. . .innovative tasks organization, support for developing the knowledge that is needed for successful task completion, and building a sense of competence (p. 122).

Thus, elementary science educators have an important opportunity (and responsibility) to help nurture and sustain elementary students' interest in science and their willingness to take risks in science. As the results of this study indicate, interest and IRT seem to go hand in hand. Moreover, as Hidi and Renninger (2006) have explained, a central goal of supporting students' interest development is helping them transition from relying on more external supports (teachers providing students with science questions to answer) to more internal supports (students generating their own curiosity questions about science). This transition from external to internal supports, consequently, requires students to be willing to take greater intellectual risks as they will be increasingly encouraged to ask their own questions and ''connect their present understandings with alternative perspectives'' (Hidi & Renninger, 2006, p. 122).

At this point it seems safe to speculate that students' interest in science is an important factor when attempting to understanding what might contribute to students' willingness to engage in IRT. As such, efforts aimed at sparking and sustaining students' interest in science likely will pay-off in the form of increasing students' willingness to engage in IRT. Still, additional research is needed to further examine how and to what extent supporting students' science interest will, in turn, result in students' willingness to take risks in their science learning.

Creative Self-Efficacy and IRT

This study also found a unique and positive relationship between elementary science students' creative self-efficacy and their reports of IRT. This finding builds on previous scholarship that has demonstrated a link between positive self-beliefs and adaptive risk taking (Bandura, 1997; Miller & Byrnes, 1997) and offers new insights into the relationship between creative self-efficacy beliefs and elementary students' IRT. Specifically, results of the regression analysis indicate that students were significantly more likely to report that they took risks in their science learning if they also viewed themselves as imaginative and confident in their ability to generate novel and adaptive ideas, develop their own scientific experiments, and come up with new ways to approach scientific problems. Conversely, students who felt less competent in their scientific imagination and ability to generate new and useful science-related ideas were less likely to report a willingness to take intellectual risks when learning science.

These finding further highlight the important role that students' self-beliefs about ability (in this case, creative self-efficacy) play in IRT—seemingly even more so than external measures of ability (Miller & Byrnes, 1997). Although, additional research is needed to examine the specific nature and consistency of this link with respect to IRT in science education, it is likely that the link between creative self-efficacy and IRT is reciprocal. As Bandura (1997) has pointed out, efficacy beliefs often are reinforced from successfully engaging in challenging (i.e., intellectually risky) activities; which, in turn, increase the likelihood that students will seek out similar challenges in the future. Thus, subsequent research should focus on examining to what extent students' creative self-efficacy both predicts and is reinforced by taking risks when learning science.

The link found between creative self-efficacy and IRT also highlights the importance of science learning environments that encourage and support students in developing their creative self-efficacy beliefs. Without a supportive classroom environment, the development of positive efficacy beliefs and associated willingness to engage in IRT seems highly unlikely. Creative self-efficacy beliefs (like all forms of efficacy) have been found to be influenced by positive ability related feedback (Bandura, 1997; Beghetto, 2006).

At this point, additional research is needed to further examine the nature of the link between creative self-efficacy and students' willingness to take adaptive risks when learning science. Until then, science educators interested in supporting students' willingness to take adaptive intellectual risks when learning science seem well advised to consider how they might create science learning environments that are supportive (rather than dismissive) of unexpected (or otherwise creative) ideas. In this way students will be more likely to invest the intellectual energy necessary for taking the risks of sharing their ideas (Kennedy, 2005). A good start might be providing students with models of successful scientists who illustrate the importance of creative ideation in their work (Dunbar, 1997; Feist, 2006) and also encourage students to view their own development of scientific knowledge as resulting from the creative and imaginative process of scientific inquiry as opposed to viewing science as "truths to be memorized" (Bransford & Donovan, 2005).

Perceived Teacher Support and IRT

Finally, the results of this study provide additional evidence for the importance of students perceiving teachers as being supportive when it comes to students' willingness to engage in IRT. The findings of this study indicate that (after controlling for all other factors in the model) students' perceptions of teacher support contributed significantly and uniquely to students' reported willingness to engage in IRT. These findings highlight the importance of creating classrooms that welcome (rather than dismiss) students' ideas and preconceptions.

It makes sense that students would be less willing to share their ideas and engage in other forms of IRT if they perceive their teachers as being dismissive or otherwise unsupportive of their ideas and abilities. As such, science learning environments need to send the message—loud and clear—that taking risks in the form sharing tentative ideas, asking questions, and trying out new learning strategies is worth the effort and risk. This is of particular importance given prior research that has documented dismissive (rather than supporting) patterns of classroom interactions between teachers and students. For instance, Black and Wiliam (1998) have explained that when teachers dismiss students' risky (and seemingly unorthodox) attempts to understand and work through problems, "over time [students] get the message: they are not required to [take the risks necessary] to think out their own answers" (p. 143).

Similarly, Kennedy (2005) has reported that teachers "habitually" dismiss unexpected (or risky) student ideas because they want to maintain the momentum of their lesson. Such practices are highly problematic for the development of robust understanding in any subject area, but seem particularly problematic for helping students develop their ability to reasoning scientifically and take the intellectual risks necessary for developing scientifically sound conceptions.

Although there are no failsafe prescriptions for creating learning environments conducive to eliciting and supporting IRT in science education, recent scholarship in science education has pointed to considerations and approaches that seem promising. For instance, Chin (2007) has developed a framework of questioning approaches that may help science educators move away from "teaching as telling" and instead encourage students to share their ideas and preconceptions. Similarly, research on the of role of argumentation in science learning (von Aufschnaiter et al., 2008) has demonstrated that in order for students to express and refine their scientific ideas through argumentation, learning activities need to be related to students' prior knowledge and at a level difficulty just beyond the students current understanding.

Teacher educators also play an important role in helping prospective teachers developing the awareness and knowledge necessary for creating learning environments conducive to eliciting and supporting IRT in science education. For instance, teacher educators can help prospective teachers actively explore their own conceptions and interpretations of their future students' (unique and sometimes unorthodox) science ideas and prior knowledge. This may be of particular importance given that prior research has found patterns in prospective teachers' general preferences for the expression of expected (as opposed to unique) ideas during classroom discussions (Beghetto, 2007b) as well as somewhat narrow conceptions of students' prior knowledge that (left unchecked) may underwrite dismissive (or ''non-responsive'') science teaching and assessment practices (Otero & Nathan, 2008). In working with prospective teachers, teacher educators are well advised (as Otero & Nathan, 2008 have stressed) to treat prospective teachers' prior conceptions as they would have future teachers treat young students' prior knowledge and ideas: as potential learning resources (rather than stable misconceptions) that can be leveraged in support of creating science learning environments conducive to IRT.

Limitations

Several important limitations should be considered when interpreting the findings of this study. First, the study may have been limited by the measurement instrument used, which relied on self-report data. Given that self-report data can be biased by flawed self-assessments (Dunning, Heath, & Suls, 2004), subsequent research (using multiple methods and measures) is also needed to verify the consistency and accuracy of the present findings. For instance, subsequent research should include observational measures of risk taking behaviors and examine behaviors over time and in multiple contexts.

Moreover, subsequent research is needed to examine the directionality of relationships among these factors. Although IRT served as the outcome measure in this exploratory study, it is quite possible that IRT has a reciprocal relationship with these factors (IRT may influence science ability, creative self-efficacy, interest in science, and perceptions of teacher support). Subsequent work is also needed to explore the various relationships among these variables and work towards developing and testing IRT theories in science. Such theory testing and refinement efforts likely will benefit from the use of more advanced analytic techniques (structural equation modeling). Finally, given the homogeneity of study participants, follow-up studies will need to sample from more diverse populations in order to verify the consistency, adequacy, and generalizability of the present findings. Even with these limitations, the results of this study offer new and potentially important insights regarding factors associated with students' IRT in science education. These findings can help guide subsequent research and practice aimed at understanding and supporting students' adaptive risk taking when learning science.

Notes

[1]Participants in this study were drawn from a larger sample ($N = 1{,}042$) of students. Of that larger sample, 65% ($n = 674$) included teacher ratings of science ability. Given the potential theoretical importance of examining the relation between ability and IRT (Clifford et al., 1990; Miller & Byrnes, 1997), it was decided that only students ($n = 587$) who had complete records, which included teacher ratings of ability, would be analyzed in this study. Although there were no substantive differences found between the results reported in this study (using listwise deletion) and results when missing values were imputed (using maximum likelihood estimation), the potential for non-randomness in missing values warrants some caution in generalizing findings reported herein. Even with this limitation, findings based on these data still offer potentially important insights that can inform and guide subsequent research on IRT in science education.

[2]Results of parallel analysis (using *MacParallel*, Watkins, 2000) initially suggested three factors for extraction. Conversely, Scree plot analysis suggested four factors for extraction. Four factors also made the most sense conceptually (as items used in this study were intended to measure four constructs). Given that over-factoring generally is less serious a problem than under-factoring (Watkins, 2006; Wood, Tataryn, & Gorsuch, 1996), four factors were extracted. The resulting pattern coefficients (reported in Appendix) supported a four factor solution, which remained consistent across various extraction (Maximum Likelihood, Principal Components) and rotation methods (Varimax).

Data used in this research were drawn from a GK-12 Project Grant funded by the National Science Foundation DGE-0338153.

Appendix: Items and Rotated Factor Pattern Matrix

Items	Factor 1	Factor 2	Factor 3	Factor 4
Intellectual risk taking ($\alpha = 0.80$)				
During science, I like doing new things even if I am not very good at them	−0.059	**0.525**	0.309	−0.033
During science, I share my ideas even if I am not sure they are correct	0.093	**0.499**	−0.023	0.039
During science, I will try to do new things even if I am not sure how	0.056	**0.692**	−0.037	−0.013
During science, I try to find new ways of doing things even if they might not work out	0.071	**0.793**	−0.063	−0.069
During science, I try to learn new things even if I might make mistakes	−0.008	**0.629**	0.114	0.044
During science, I ask questions even if other students will think I am not as smart as them	−0.023	**0.505**	−0.136	0.134
Interest in Science ($\alpha = 0.77$)				
I like science	0.070	−0.113	**0.882**	−0.039
Science is important to me	0.011	0.312	**0.407**	0.028
I like what we do in science	−0.070	0.054	**0.667**	0.018
Science is my favorite subject	0.059	−0.097	**0.666**	0.041
Creative Efficacy in Science ($\alpha = 0.83$)				
I am good at coming up with new ideas during science class	**0.701**	−0.001	0.027	0.082
I have a good imagination during science class	**0.687**	−0.014	0.064	−0.063
I have a lot of good ideas during science class	**0.810**	−0.039	0.002	0.065
I am good at coming up with my own science experiments	**0.582**	0.053	−0.003	−0.029
I am good at coming up with new ways of finding solutions to science problems	**0.557**	0.215	−0.043	−0.041
Perceptions of teacher support ($\alpha = 0.77$)				
My teachers really listen to my ideas	−0.071	0.183	0.065	**0.576**
My teachers have told me that I have a lot of creative ideas	0.040	−0.103	−0.017	**0.885**
My teachers have told me I am good at science	0.015	0.146	0.008	**0.561**

Note: $N = 585$. Principal Axis Factoring using Promax rotation with Kaiser Normalization. Pattern Coefficients ≥ 0.40 in bold.

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