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Statistical literacy in the middle school: The relationship between interest, self-efficacy and prior mathematics achievement[1]

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ABSTRACT

This paper examines the relationship between key predictors of middle school students' interest for statistical literacy, including their self-efficacy for statistical literacy and their prior mathematics achievement. Given the lack of research in the statistical literacy domain, a review of the mathematics education literature confirms the importance of self-efficacy and achievement in predicting interest and describes the nature of their influence on interest. The paper then reports on an empirical study involving a sample of 438 Australian middle school students from 8 schools across 3 states. Data from this study are used in a series of statistical models to confirm the influence of identified predictors and to study their inter-relationship. Results from the study suggest that the influence of prior achievement on interest is completely mediated by self-efficacy. In addition to this, the relationship between interest and self-efficacy appears to be quadratic, in that students with high levels of self-efficacy may not have corresponding high levels of interest. Implications for this research are then discussed.

INTRODUCTION

It is imperative that citizens of the 21st century have the necessary skills to interact in a meaningful way with the increasing volumes of information that they encounter; information that in many instances contains statistical elements such as graphs and tables. Yet in this time of rapid change, researchers report that Australia is unable to educate a sufficient number of skilled graduates in mathematics (Australian Academy of Science, 2006) and statistics (Trewin, 2005). Such skill shortages are influenced by the reported declines in the numbers of students in senior secondary school who opt to take the higher level mathematics courses that lead into tertiary study (Forgasz, 2006). Students' choice of mathematics course is influenced by a number of factors that include: their interest and liking for mathematics, their previous achievement in mathematics, their mathematics self-concept, and their perceptions regarding

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the usefulness and difficulty of mathematics (McPhan, Morony, Pegg, Cooksey, & Lynch, 2008). Of these factors, evidence suggests that interest is dominant (Watt, 2005; Wigfield, Tonks, & Eccles, 2004): Students are more likely to re-engage in any activity if they are interested in it. This study seeks to address the reported skill shortages in statistics through an investigation of middle school students' interest for statistical literacy. Such literacy is defined as an ability to interact critically with messages containing statistical elements (Gal, 2003) and the underlying skills of this literacy are developed in the chance and data strand of all Australian P-10 mathematics syllabi.

Although the underlying concepts of statistical literacy are embedded in the mathematics curriculum, it is assumed that students encounter statistical messages in a wide variety of contexts both in and out of school. Consequently statistical literacy is more than a topic of the mathematics curriculum. In fact statistics itself is regarded as a methodological discipline that is distinct from mathematics (Moore, 1988). The importance of statistical literacy is reflected in the proposed Australian National Mathematics Curriculum (National Curriculum Board, 2009), which identifies chance and data as one of three content strands. It is no surprise, therefore, that researchers have explored the development of statistical literacy in both school students (Watson, 2006) and adults (Gal, 2003; 2004). Indeed Callingham and Watson (2005) have used students' performance in statistical literacy related tasks to map out a detailed hierarchy for the domain. Although these studies note the importance of affective elements, none have explored their influence in this domain. This study seeks to fill this gap in the literature through an investigation of middle school students' interest.

A review of the literature suggests that middle school students' interest for statistical literacy should be influenced by a number of factors that can broadly be classified as those relating to the individual and those relating to the actual learning situation (Carmichael, Callingham, Watson, & Hay, 2009). In this study, the focus is primarily on the former, although the influence of the teacher is also explored. Given this focus, the research question is: How do variables such as age, prior achievement, gender, and self-competency beliefs, contribute to middle school students' interest for statistical literacy?

Theoretical review

The discussion in this section commences with a theoretical review of the interest construct. It then identifies key predictors of interest that are unique to the individual and in particular establishes the importance of students' ages, self-competency beliefs and prior mathematics achievement on their assessments of interest. The discussion concludes with an examination of the influence of the teacher on students' interest.

Interest is an affect with both trait and state properties. At the trait level *individual interest* is a valuing of an interest object, so much so that it becomes identified with the self (Dewey, 1910). Having such interest is considered to be essential for psychological health (Hunter & Csikszentmihalyi, 2003). At the state level, *situational interest* is identified as one of several basic human emotions (Izard, 1984) and is considered to be similar to the motivational state of curiosity (Silvia, 2001). Theories of interest development suggest that situational interest can emerge into individual interest (Hidi & Renninger, 2006; Krapp, 2007).

In an educational setting, the interest assessed through pen and paper instruments is regarded as a form of individual interest, where it is defined as a student's "relatively enduring predisposition to reengage particular content over time" (Hidi & Renninger, 2006, p. 113). Students with such an interest for a particular subject are known to display deeper levels of cognitive processing, greater use of self-regulatory learning strategies and provide more positive ratings on the quality of the learning experience, than their disinterested peers (Schiefele, 1991).

The adolescent students that inhabit middle schools find themselves undergoing significant physical and psychological changes. In regard to the latter, researchers argue the primary role of adolescence is that of identity formation (Hay & Ashman, 2003). Such students typically become more attuned to the interests of their peers and use these to help define the self (Krapp, 2007). It is not surprising, therefore, that researchers report declines in the levels of interest that students have for learning in general (Dotterer, McHale, & Crouter, 2009) and for specific domains such as mathematics (Watt, 2008). It is therefore expected that age will have a negative influence on middle school students' interest for statistical literacy.

Krapp (2007) argued that the development of interest is directed by two psychological control systems, the cognitive and the emotional. In regards to the former, he argued that students consciously direct their interest towards certain objects in order to achieve goals. In a school setting many students have achievement related goals and their interest for attaining these goals will be influenced by their self-competency beliefs. This association between interest and self-competency beliefs, in the form of mathematics self-concept, is confirmed in the secondary mathematics context (Trautwein, Ludtke, Köller, Marsh, & Baumert, 2006). Self-concept, however, is a reflective construct (Bong & Skaalvik, 2003) that is primarily based on students' perceptions of their past achievement experiences. Self-efficacy, which is defined as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura, 1997, p.3), is a forward-looking construct. Apart from past mastery experiences, self-efficacy is also influenced by the vicarious experiences of others, the persuasion of significant others and even immediate physiological factors (Bandura, 1997). Of all the psychosocial factors, self-efficacy is reported to be the best predictor of achievement in an educational context (Robbins et al., 2004).

The expected relationship between self-efficacy and interest may be more complex than the reported linear association between self-concept and interest (Trautwein et al., 2006). It is thought that one of the mechanisms for evoking the interest state is a person interaction with a collative variable such as novelty or uncertainty (Berlyne, 1960). In relation to this, Silvia (2003) argued that there is a degree of uncertainty associated with students' self-efficacy assessments and that this uncertainty will manifest itself in a quadratic way on their associated interest. More specifically, students with low levels of self-efficacy for a given task are certain that they cannot master it and as a result will lose interest. On the other hand, students with high levels of self-efficacy are certain that they can master the task and as a result will also lose interest. Students with mid-levels of self-efficacy, those with sufficient uncertainty regarding their mastery of the task, are expected to report the most interest.

In regards to prior achievement, the "Model of Domain Learning (MDL)" (Alexander, 2003) predicts that the acquisition of knowledge in a domain will be accompanied by increased levels of individual interest. This association between prior achievement and interest has been confirmed in the mathematics domain (Köller, Baumert, & Schnabel, 2001). More recently, however, Trautwein et al. (2006) reported that students' achievement relative to their peers is a stronger predictor of interest than their absolute achievement. They also reported that the influence of students' self-concept almost entirely mediates the relationship between their achievement and interest.

Research suggests that gender will also influence interest. For example Köller et al. (2001) reported that boys have higher levels of interest for mathematics than girls. In addition to this, Schiefele, Krapp, and Winteler (1992) reported that the association between achievement and interest is stronger for boys than for girls. It is not clear, however, whether such reported gender differences will occur in this context, especially given reported gender differences in students' interest for some of the topics and activities associated with the acquisition of statistical literacy (Carmichael & Hay, 2009b).

As mentioned, features of the learning situation are thought to contribute to students' situational interest and ultimately their individual interest. The class teacher is the primary architect of what happens in the learning environment and therefore should exert some influence on students' interest. For example, teachers' provision of structure during a lesson is known to have a positive impact on students' interest (Kunter, Baumert, & Köller, 2007).

Given the identified predictors of middle school students' interest for statistical literacy, the discussion in the next section describes methods for obtaining relevant measures and the subsequent modelling of these measures in order to confirm their influence on interest and to explore their inter-relationship.

METHOD

The data collection in this study commenced with the selection of a representative sample of Australian middle school students. From these students a number of data were then collected that included measures of their interest, self-efficacy and prior achievement. These data were then analysed using a series of regression equations. The discussion in this section describes each of these stages.

Sample selection

The sample of 438 students used in this study was a sub-sample of 791 students participating in an interest study for whom prior mathematics achievement data were available. The larger sample represents those from a total of 1384 invited students who agreed to participate in the interest study, a response rate of 57%. It was a convenience sample[3] of the Australian middle school population, which can be assumed to consist of approximately equal proportions of each gender, equal proportions of students in each of years 7, 8, and 9, and a range of school types including both Government and Independent schools.

The 438 students reported in this study attended six independent and two government schools from three Australian states. Of the students in this sample, 54% were from Tasmania, 29% from Victoria and the remainder from Queensland. Most students (69%) attended independent schools and the majority (85%) were in Years 7, 8 or 9. The mean age of students in this study was 13.6 years and just over one half (53%) were male.

Instruments used and data collected

All students were asked to complete the Statistical Literacy Interest Measure (SLIM), a previously validated interest instrument (Carmichael, 2008) that contains 16 self-descriptions, which students respond to using a five-point Likert scale. An interval measure of interest was constructed using the Rasch Rating Scale Model (Andrich, 1978) with the software package *Winsteps* (Linacre, 2006) and all students were assigned an interest score. For this sample of students, SLIM explained 67% of the variance in their responses and reported an estimated internal reliability coefficient of $\alpha = 0.91$.

Students also completed the Self-efficacy for Statistical Literacy (SESL) scale, also previously validated (Carmichael & Hay, 2009a), that contains nine self-descriptions with the same five-point Likert scale. As with the interest measure, a Rasch measurement paradigm was adopted for the construction of the self-efficacy measure, which was used to assign each student a self-efficacy score. For this sample of students, SESL explained 70% of the variance in their responses and reported an estimated internal reliability coefficient of $\alpha = 0.93$.

Teachers of students provided estimated ratings of their students' prior achievement in mathematics, with such ratings ranging from E, the lowest grade, to A. These grades reflect the reporting measures used in Australia, which were mandated by the Commonwealth Government (Department of Education, Science and Training, 2005). Given that grades of E and D represent less than satisfactory achievement, these categories were collapsed into one denoted F. Consequently, of the 438 students in the study, 36 were assigned a grade of F, 106 a grade of C, 182 a grade of B and 114 a grade of A. Given the hypothesised importance of students' prior achievement relative to their class, an additional four category prior achievement variable was constructed in which students' achievement grades were compared to the median grade of their class. Of the 438 students in the study, 27 had an achievement two grades below the class median, 89 had an achievement one grade below the median, 219 achieved the median grade, and the remainder had an achievement one grade above the median.

In addition to prior achievement, interest and self-efficacy data, demographic data including students' ages, gender and school attended were collected. Information regarding the class and teacher each student was assigned was only available for 411 students.

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[3] Since the sample was non-random, cited *p*-values are notional, as are tests of statistical significance.

Analysis

Bivariate relationships between interest and its hypothesised predictors were initially used to identify their statistical significance. Latent regression models (Adams, Wilson, & Wu, 1997) were then used to analyse the inter-relationship between interest, self-efficacy, prior mathematics achievement and other individual factors. Such models allow for the inherent measurement error in the response variable, in this case the interest and/or self-efficacy measures, and were implemented using the software package *Conquest* (Wu, Adams, Wilson, & Haldane, 1998). They do not allow for the inherent measurement error in predictor variables, however in such instances coefficient estimates can be attenuated for error (Aiken & West, 1991).

As no teacher specific variables were available in this study, the influence of the teacher was examined through the use of mixed effects models (Faraway, 2006), which cater for any dependency between subjects in given groups. In this study students were grouped by class and it assumed that any dependency is attributed, in part, to the influence of their teacher. These models were applied using the software package *R* (R Development Core Team, 2009).

RESULTS

The discussion in this section commences with a report of significant bivariate relationships between interest and other measured variables. It then reports the application of latent regression models to students' interest responses and also their self-efficacy responses. The discussion concludes with a report of the application of mixed effects models to students' interest scores.

Students' interest scores were moderately associated with their self-efficacy scores $(r = .63, p = .00)$. The strength of this association is similar in magnitude to the average value of .59 reported by Rottinghaus, Larson, and Borgen (2003) in their meta-analysis of 60 self-efficacy/interest studies. Students' relative prior achievement in mathematics influenced their interest scores $(F = 3.85, p = .01)$, although the greatest differences in group means occurred between students with an achievement two grades below median and the other groups of students. Interestingly, students' absolute prior mathematics achievement had a greater influence on their interest $(F = 11.47, p = .00)$ than their relative prior achievement. There was no significant linear association between the ages of students and their interest scores.

A series of latent regression models were then used to analyse the inter-relationship between these significant predictors of interest. Of the available predictors of interest, only students' self-efficacy scores and ages were statistically significant. In the presence of self-efficacy the reported influence of prior achievement was not significant. In order to assess the proposed quadratic association between self-efficacy and interest, the square of the former was also included in the model. This term was found to contribute significantly and reduced model deviance by 33.44. This reduction is approximately chi-square distributed on one degree of freedom and hence represents a statistically significant, albeit small, improvement in model fit. Coefficients and their standard errors for the resulting model are reported in Table 1 as Model 1. This table also includes the estimated R-square and reported deviance for the model.

Given that prior mathematics achievement was not a predictor of interest; a model was created with self-efficacy as the response variable. In this instance, prior mathematics achievement contributed to explaining self-efficacy, as did age and interest. Gender, however, was not a significant factor. The details of this model are reported in Table 1 as Model 2. The influence of prior achievement was modelled using contrasts so that compared to students with an achievement two grades below the class median an achievement of one grade below the median will contribute an additional 0.160 logits of self-efficacy, a median grade achievement will contribute an additional 0.454 logits, and an above median grade achievement will contribute an additional 0.614 logits.

Table 1: Details for Models 1 and 2

Variable	B	$se(B)$
Model 1		
Constant	0.762	0.509
Age (years)	-0.065	0.028
Self-efficacy (logits)	0.424	0.020
Square of self-efficacy	-0.045	0.006
R^2 = .50, Deviance = 19935		
Model 2		
Constant	-2.524	0.860
Age	0.169	0.034
Prior achievement contrast 1	0.160	0.090
Prior achievement contrast 2	0.454	0.100
R^2 = .51, Deviance = 11326		

A series of mixed effects models were applied to students' interest scores using the significant predictors identified in Model 1 and with students' class membership as the grouping variable. In order to model any dependence between students in the one class, a random effect in the constant term was assessed for significance. In this instance, however, the influence of age in the model became insignificant, presumably because students within the same class have similar ages. Re-applying the mixed effects model without age as a fixed effect and with a random effect in the constant term generated a model with two significant predictors, namely self-efficacy and its square. The specified model is: $Interest = (-0.16 + b) + 0.44SE - 0.05SE^2 + \varepsilon$, where b represents the random effect in the constant term, *SE* the student's self-efficacy score, and ε the residual error. The variance associated with the random effect b is reported as $\sigma_b^2 = 0.03$, while the residual variance is $\sigma_\varepsilon^2 = 0.63$. Further details of the model are reported in Table 2.

Table 2: Details for Model 3

Variable	B	$se(B)$
Constant	-0.16	0.06
Self-efficacy (logits)	0.44	0.03
Square of self-efficacy	-0.05	0.01
Deviance = 990		

Compared to a simple linear regression model with age, self-efficacy and its square as predictors, this model reduced deviance by 4.3. This reduction in deviance is chi-square distributed on one degree of freedom and is statistically significant at the 5% level. Consequently the model improves fit on a standard linear model, but only slightly. It does not, however, provide useful information regarding the influence of the teacher. This is because the random effect in the constant term also models the influence of students' ages. In general, classes with lower average levels of interest were those with older students. In addition to this, the variance associated with the class grouping $(\sigma_b^2 = 0.03)$, is much smaller than the variance associated with the residual error $(\sigma_{\varepsilon}{}^{2} = 0.63)$, suggesting that compared to the noise in the model, the influence of class grouping is relatively minor.

DISCUSSION

The analysis confirms that students' self-efficacy for statistical literacy is a key predictor of their interest and that the relationship is quadratic. The analysis also confirms the findings of Trautwein et al. (2006) that self-competency beliefs, in this case self-efficacy, completely mediate the influence of prior achievement on interest. The quadratic relationship supports Silvia's (2003) contention that more confident students lose interest in tasks that they are certain they can successfully complete. As expected, age did have a negative influence on interest, but only when controlling for self-efficacy.

The lack of a gender effect in predicting both interest and self-efficacy is noteworthy, especially in light of reports that boys show higher levels of interest (Köller et al., 2001) and self-efficacy (Hyde & Durik, 2005) for mathematics than girls. This may point to distinctive differences between the mathematics and statistical literacy domains, in that the latter also involves a facility with language where girls are known to display higher levels of self-efficacy than boys (Hyde & Durik, 2005). In addition to this, there are contexts associated with statistical literacy that girls tend to find more interesting than boys (Carmichael & Hay, 2009b).

Although it is expected that the teacher will have an influence on students' interest, the results of the mixed effects models were inconclusive. In the first instance a random class effect, so presumably a teacher related effect, was significant in the constant term. This only occurred, however, when age was removed as a fixed effect from the model and included as random effect in the constant term. In the second instance, the variation associated with the class grouping term was relatively small when compared with the residual error suggesting that its influence on interest is relatively minor.

Given the strong influence of interest on self-efficacy, a reciprocal effects model might be appropriate in that students with high levels of interest for statistical literacy will be likely to engage in the domain, gain competence and thus self-efficacy. Increased levels of self-efficacy, in turn, are then likely to promote further engagement and thus interest. In a study involving the self-concept construct, Marsh, Trautwein, Ludtke, Köller, and Baumert (2005) found some support for a reciprocal effects model, although they reported stronger support for self-concept predicting later interest than the reverse.

Limitations of the study

There were limitations associated with the methodology. In the first instance it was not possible to select students randomly. Given that participation was voluntary, students in this sample may have displayed different interest characteristics than those who chose not to participate.

A second limitation of the study concerns the use of latent variables and the inherent measurement error associated with such variables. This was overcome in Models 1 and 2 through the use of latent regression models, although these did include predictor variables that contained measurement error. The aim of this study, however, was to investigate the inter-relationship between interest, achievement and self-efficacy and not specifically the size of effects. The two latent regression models, therefore, served this purpose. The mixed effects models did not account for measurement error in any variable and this could have contributed to the inclusive results obtained from these models.

Implications and future research

The research reported in this paper suggests that students' competency valuations are a strong predictor of interest. This result is not unexpected with cited papers reporting such a relationship. Indeed studies involving the concept of *flow* (Csikszentmihalyi, 2002), which is an extreme form of interest where total involvement with an activity occurs, report that positive competency valuations are a necessary precondition for flow. Further, in order for flow to occur, students must perceive that a balance exists between the perceived challenge of the task and their perceived competence. Students who do not perceive sufficient challenge in the task or who see the task as too challenging are unlikely to experience flow. The quadratic relationship reported in this study supports this notion of an optimum level of challenge in order for interest or flow to occur. More recently, Csikszentmihalyi, Abuhamdeh, and Nakamura (2005) argued that some students may need external support during the initial stages of an activity in order to gain sufficient competence valuations. That given this support and sufficient challenge in the activity an emergent motivation may develop, making it more likely that the students will experience flow. Given the key role that competence valuations appear to have on interest and the importance of it as an outcome variable, further research needs to occur at the task level with a view to ascertaining how support can increase middle school students' levels of self-efficacy during their interaction with specific tasks.

The MDL predicts a positive association between students' knowledge and interest. In this study no measures of statistical literacy knowledge were available, yet students' prior mathematics achievement did not have a direct influence on their interest for statistical literacy. This lack of a direct relationship could be due to differences in the domain, although, as discussed, studies in mathematics have reported similar findings. Much of the reported empirical testing of the MDL has occurred in an undergraduate context where students are older and likely to have more stable emotions than middle school students (Larson, Moneta, Richards, & Wilson, 2002). Further research in the statistical literacy domain with a larger randomised sample and with statistical literacy knowledge measures could provide valuable information regarding the efficacy of the MDL in the adolescent context.

As discussed, the lack of reported gender effects on both interest and self-efficacy could be associated with gender differences in students' achievement goal orientations, in that girls are likely to show higher levels of mastery and performance goals than boys in stereotypically female domains such as language (Hyde & Durik, 2005). More recent research has established a link between students' use of mastery achievement goals and increased levels of their interest (Hulleman, Durik, Schweigert, & Harackiewicz, 2008). Further research in the statistical literacy domain should consider the goal orientation of students and the impact that gender has on this and subsequent interest.

The regression models reported in this paper explained at most 51% of the variance in measured variables. Consequently there is quite a large proportion of unexplained variance. Apart from demographic variables, only measures of students' self-efficacy and prior mathematics achievement were available. Given the earlier discussion regarding the influence of the teacher and the suggestion that external support needs to be provided for some students in order to experience the interest state, further research in this area would benefit from the inclusion of teacher level variables, especially that of teacher support.

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