Predictors of middle school students’ self-efficacy in statistical literacy
Colin Carmichael, Charles Sturt University, ccarmichael@csu.edu.au

Abstract
Statistical literacy is an ability to critically interact with messages that contain statistical elements. In our information rich age, such literacy is becoming increasingly important. Theoretical models of statistical literacy suggest that in addition to some requisite statistical and mathematical knowledge, statistically literate citizens must possess certain dispositions, including curiosity and scepticism. It is argued that a focus on students’ self-efficacy in statistical literacy during their learning of statistical concepts will promote these dispositions. Accordingly, this study explores predictors of middle school students’ self-efficacy in statistical literacy. It commences with an examination of four theoretical sources of self-efficacy, including: prior mastery experiences, the vicarious experiences of others, verbal persuasion from significant others, and physiological states. The study then identifies variables that reflect some of these sources and from there builds a linear regression model to predict self-efficacy in this context.

The study is based on data obtained from a representative sample of 425 middle school students, enrolled in schools from three Australian states. Predictor variables include students’ prior achievement, age, gender and their year level at school with respect to the primary/secondary transition. In order to explore the influence of the vicarious experiences of others, the study also considers frame specific self-concepts. More specifically it assesses students’ competency based beliefs with respect to an external frame of reference – comparison with peers – and their competency based beliefs with respect to an internal frame of reference – comparison with other subjects. Self-efficacy measures are based on students’ responses to a previously validated, nine-item self-efficacy scale analysed using the Rasch rating scale model. These variables were then used in series of linear regression equations to predict middle school students’ self-efficacy in statistical literacy.

The results of the study indicate that middle school students’ self-efficacy beliefs in the statistical literacy context are influenced by their prior achievement in mathematics and to a lesser extent their age. In addition to this, external ability comparisons rather than internal comparisons of subject performance appear to predict self-efficacy, supporting the view that the vicarious experiences of others are a source of self-efficacy. Implications of these results are discussed in the paper.

Introduction
Many issues of concern to the general public require a rudimentary understanding of statistical concepts. Informed debate surrounding climate change, for example, requires knowledge of sampling variation. In order to equip our children with the skills necessary to make informed contributions to such debates, we need to ensure they are statistically literate, that is they should have the ability to interact critically with messages containing statistical elements (Gal, 2003). It is expected that the underlying concepts and skills for this literacy will be developed in the Statistics and Probability strand of the National Curriculum in Mathematics (Australian Curriculum Assessment and Reporting Authority, 2011), one of only three content strands. This curriculum mandates that children will encounter statistical and probabilistic concepts in each year of their school education up until the end of Year 10. Moreover, it recommends a cross-curricular approach to the teaching of numeracy, so it is expected that children should develop their statistical literacy in other subjects such as the social and natural sciences.
Theoretical models that describe the development of statistical literacy have been proposed (Gal, 2002; Watson, 2006). Based on the expected outcomes of citizens, Gal (2002) proposed a model of statistical literacy that included: literacy skills; knowledge of statistical concepts, mathematics, and context; and, dispositional components. With its foundations in school-based research, the model proposed by Watson (2006) also included a knowledge component and dispositions of curiosity and scepticism. As is discussed, students’ cognitive and affective development in statistical literacy are both likely to be influenced by a confidence in their ability to successfully complete statistical tasks, in other words by their self-efficacy in statistical literacy. The current study focuses on factors that contribute to this self-efficacy.

Theoretical background
Self-efficacy 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). Students with such beliefs are known to participate more readily, work harder and persist longer in learning tasks than their less confident peers (Bandura, 1997). Moreover such students are also likely to set more challenging learning goals than those who are less self-efficacious (Zimmerman, Bandura, Martinez-Pons, 1992). Achieving these goals leads to the acquisition of domain knowledge and with this interest (Alexander, 2003). In summary, self-efficacy is an important construct known to positively influence cognitive and affective development.

Self-efficacy is assessed at a task level, where students are asked to indicate their level of confidence in successfully completing a given task. Arguably self-efficacy measures that require students to gauge their confidence at the domain level, for example confidence in mathematics, assess broader constructs such as self-concept (Pajeres & Miller, 1994). Students’ self-efficacy beliefs are thought to emerge from four sources: their prior mastery experiences; the vicarious experiences of others; verbal persuasion from others; and, physiological factors (Bandura, 1997). The following discussion examines these sources and develops suitable explanatory variables for a model that predicts middle school students’ self-efficacy in the emerging domain of statistical literacy.

Prior mastery experiences
Students’ mastery experiences with learning tasks are believed to be the major source of self-efficacy (Schunk, 1991), in that success in a given task is likely to serve as a benchmark for self-efficacy in similar tasks. Valid measures of prior achievement are likely to reflect students’ mastery experiences and consequently several studies have reported a close association between prior achievement and self-efficacy (Carmichael & Taylor, 2005; Multon, Brown, & Lent, 1991; Robbins et al., 2004). Strong associations are reported when the self-efficacy instrument uses tasks that
closely align with those in the achievement measure – see for example, Pajeres and Graham (1999).

**The vicarious experiences of others**

In relation to the second source of self-efficacy, Schunk (1991) asserted that students may draw upon the experiences of their peers when required to form a self-efficacy assessment for an unfamiliar task. In other words, if peers of the same perceived competence can successfully complete the task then it is likely that students will see themselves as being successful. Such a comparison hinges on students’ beliefs regarding their competency with respect to others.

Students self-competency beliefs form a part of their academic self-concept, which is a collection of self-perceptions formed through the interpretation of one’s experiences with the environment and influenced by the views of significant others (Schunk, 1991). Arguably self-efficacy beliefs form a part of one’s self-concept and the two constructs – self-efficacy and self-concept – are closely related (Zimmerman, 2000). It is widely believed that academic self-concepts are frame-specific in that students use the performance of their peers as an external frame of reference (Bong, 1998; Marsh, 1990; Skaalvik & Rankin, 1990). In order to explain somewhat paradoxical results – strong correlations between maths and verbal achievement but zero or negative correlations between maths and verbal self-concepts – Marsh (1986) proposed that students also use an internal frame of reference, in that they compare their performance in one subject with their performance in other subjects. Empirical results lend support for the use of two frames of reference in the formation of academic self-concepts (Bong, 1998; Marsh, Walker, & Debus, 1991) but not so in the formation of self-efficacy beliefs (Bong, 1998; Marsh et al., 1991; Skaalvik & Rankin, 1990). With the exception of Bong (1998), however, these latter studies were based on cross-domain comparisons of achievement and self-efficacy in mathematics and language. As discussed, assessments of confidence at this level are regarded as measures of self-concept itself and not self-efficacy. Only the one study, therefore, has examined sub-domains of mathematics (Bong, 1998), and this found no evidence to suggest that students use an internal frame of reference when forming self-efficacy beliefs.

Given that the vicarious experiences of others is thought to be a source of self-efficacy, it is likely that a measure of self-competency with respect to an external frame of reference will be a suitable predictor variable. In light of the discussion related to frames of reference and the paucity of research related to their influence on self-efficacy, a measure of self-competency with respect to an internal frame of reference should also be considered.
The social persuasion of others

The self-efficacy beliefs of some students, especially those who lack the skills to make appraisals of self, will be influenced by the social persuasion of significant others (Bandura, 1997). Evidence suggests that the cultural background (Klassen, 2004) and gender (Usher & Pajeres, 2006) of these students may moderate the influence of social persuasion. In a school setting, social persuasion from teachers is likely to play a prominent role in the formation of self-efficacy beliefs for such students.

Other predictors of self-efficacy

The influences of physiological factors are difficult to measure in empirical studies, although demographic variables such as age and gender may moderate their effects as sources of self-efficacy. In relation to age, Jacobs, Lanza, Osgood, Eccles, and Wigfield (2002) reported that students’ beliefs in their level of competency tend to decline as they progress through school, possibly because they become more adept at making social comparisons. Watt (2004), however, reported that students’ expectations of success remain relatively stable during secondary school although she noted gender differences. More recently, Marcoulides, Gottfried, Gottfried, and Oliver (2008) reported that motivational states are likely to be stable before the onset of adolescence. The primary/secondary transition may also have an influence on students’ self-efficacy in that Anderman and Midgley (1997) reported a drop in perceived academic competency during the elementary/middle school transition.

In relation to gender, several studies report that boys tend to report more positive attitudes and affect toward mathematics than girls despite little differences in achievement – see for example the meta-analysis by Else-Quest, Hyde, and Linn (2010). A similar situation appears to occur in tertiary statistics, where females report lower levels of self-efficacy than males (Awang-Hashim, O’Neil, & Hocevar, 2002). These results may reflect reported gender stereotypes in mathematics that associate high performance with males (Kiefer & Sekaquaptewa, 2007) and suggest that girls may be less self-efficacious in statistical literacy than boys.

Research question

Given the presumed sources of self-efficacy, the study aims to answer the following question: To what extent do prior achievement, frame specific self-concepts, and demographic variables such as age, gender and classroom teacher, predict middle school students’ self-efficacy in statistical literacy.

Method

Students
A purposive cluster sample design was adopted for the study in order to obtain a representative sample of the Australian middle school population. Twelve schools from three Australian states were invited to participate in the study and nine accepted. Of these nine schools, two were Government high schools, five were independent co-educational schools and the remainder were independent single-sex schools. Three schools were located in Queensland, three in Victoria and the remainder in Tasmania. These schools nominated classes of students who could participate, and these in turn were sent invitations. As a result of the process, a total of 658 students taught by 19 teachers, were invited to participate in the study and 425 returned completed survey forms, a response rate of 64%. The majority of students (56%) attended co-educational independent schools, 35% attended government schools, and the remaining attending single-sex independent schools. Most students attended school in Tasmania (60%), the remaining students attended school in Victoria (20%) and Queensland (20%).

Of the 425 students in the study, the majority were female (53%). The ages of students ranged from 11 through to 16 years, with a mean of 13.1 years. They attended classes in Year levels from 6 through to 10, although due to differences in the state jurisdictions it was decided to also record their year level with reference to the primary/secondary boundary. Using this categorization, 12% of students attended school in their last year of primary school, 32% in their first year of secondary school, 24% in their second year of secondary school, 21% in their third year of secondary school and the remainder in their fourth year of secondary school.

**Measures**

Self-efficacy was assessed through the use of the “Self-Efficacy for Statistical Literacy (SESL)” scale (Carmichael & Hay, 2009). The scale consists of nine self-descriptions – shown in Table 1 – that were answered on a five-point Likert scale ranging from 1 (*Not me at all*) to 5 (*Describes me well*). Student responses to the scale were analyzed through application of the Rasch rating scale model (Andrich, 1978) to these data using the software package *Winsteps* (Linacre, 2006). For these students, the self-efficacy measure explained 71% of the variance and reported a reliability coefficient of $\alpha = 0.92$. Self-efficacy scores for the students ranged from $-5.0$ through to 5.1 logits, with a mean of 0.01 logits.

It was not possible to obtain a measure of students’ prior achievement in statistical literacy because this literacy is not specifically assessed in any Australian subject curriculum, although its underlying statistical concepts are assessed in mathematics. Even in mathematics, only broad measures of achievement were available and these were based on teacher ratings of their students’ mathematical achievement, which are known to be closely associated with actual performance (Egan & Archer, 1985). More specifically, teachers were asked to rate their students
mathematical achievement using a five-point scale ranging from ‘A’ the highest rating, to ‘E’ the lowest, reflecting the current reporting system used in Australia (Commonwealth Department of Education, Science and Technology, 2005). These ratings were available for only 403 of the students. Of these students, 24% received an A-grade, 42% a B-grade, 25% a C-grade, 6% a D-grade and the remainder an E-grade.

Students’ self-competency beliefs with respect to the external and internal frames of reference were assessed using two items that assessed their perceived mathematics ability. As with prior achievement, it was felt that students would be unable to make accurate assessments of their self-competency in statistical literacy as it is not specifically assessed. For competency with respect to the external frame of reference, students were asked to respond to the self-description “compared to others in my class I am good at maths” – shown as the variable Ext – and for competency with respect to the internal frame of reference “out of all my subjects I usually get my best marks in maths” – shown as the variable Int. Both self-descriptions were answered using the five-point Likert scale described earlier.

Table 1

<table>
<thead>
<tr>
<th>No.</th>
<th>Item (“I am confident that I am able to:”)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Solve problems that use averages</td>
</tr>
<tr>
<td>2</td>
<td>Find when a newspaper article has used the wrong type of average.</td>
</tr>
<tr>
<td>3</td>
<td>Explain to a friend how probability (or chance) is calculated.</td>
</tr>
<tr>
<td>4</td>
<td>Show data correctly on a bar chart.</td>
</tr>
<tr>
<td>5</td>
<td>Explain the meaning of a graph in a newspaper or on the internet.</td>
</tr>
<tr>
<td>6</td>
<td>Find a mistake in someone else’s graph.</td>
</tr>
<tr>
<td>7</td>
<td>Explain when conclusions that are based on surveys might be wrong.</td>
</tr>
<tr>
<td>8</td>
<td>Arrange my data correctly into a table.</td>
</tr>
<tr>
<td>9</td>
<td>Explain how to select a fair sample of students for a school survey.</td>
</tr>
</tbody>
</table>

Analysis

In order to examine the predictors of self-efficacy, a series of linear regression models were applied to these data with self-efficacy score as the response variable, using the software package R (R Development Core Team, 2009). In order to assess any influence that teachers had on their students’ self-efficacy, a hierarchical linear model was applied to these data, as described in (Faraway, 2006), with teacher as a grouping factor.
Results

Prior to reporting the results of the regression analysis, key bivariate relationships are reported. In relation to the primary/secondary boundary, the mean self-efficacy score for primary schools students was 0.36 logits higher than the mean self-efficacy score for those in their first year of secondary; however this difference was not statistically significant. Similarly, the mean male self-efficacy score was 0.28 logits higher than the mean female score, but again this difference was not statistically significant. As expected, mathematics achievement was closely associated with self-efficacy ($F = 16.0, p = 0.00$) with students gaining higher grades more likely to report high levels of self-efficacy. Similarly, self-efficacy scores were associated with external frame of reference assessments ($F = 34.4, p = 0.00$) and internal frame of reference assessments ($F = 21.1, p = 0.00$), with students endorsing these self-descriptions being more likely to report high levels of self-efficacy. Age was positively correlated with self-efficacy ($r = .2, p = 0.00$), though this figure presumes an underlying linear relationship, which may not be the case, especially given the reported drop between primary and the first year of secondary.

Using a standard linear regression model, the only significant predictors of self-efficacy were age, external frame of reference assessments and prior mathematics achievement. In the presence of other factors, the internal frame of reference assessment was not a significant predictor of self-efficacy. Interaction terms were tested but were not found to contribute significantly to the model. The model, shown in Equation 1, explained 32% of the variance in self-efficacy scores for these students. Standard errors for coefficients are shown underneath in brackets and indicate that D-grade and B-grade terms are not significant and C-grade is significant only at the 5% level of significance. All other terms in the model are significant at the 1% level.

Model assumptions appear to have been met. The top plot in Figure 1 shows the sample quantiles against theoretical quantiles and its near linear form supports the normality assumption. The bottom plot in Figure 1 shows the model residuals against the predicted values and its random scatter supports the assumption of homogeneity in the data.

\[
\text{Self-efficacy} = -4.38 + 0.66\text{Ext2} + 1.08\text{Ext3} + 1.77\text{Ext4} + 1.93\text{Ext5} + 0.49\text{Dgrade} \\
\quad + 0.94\text{Cgrade} + 0.66\text{Bgrade} + 1.26\text{Agrade} + 0.18\text{Age} \\
\quad (0.80) \quad (0.20) \quad (0.19) \quad (0.20) \quad (0.23) \quad (0.49) \\
\quad + 0.45 \quad (0.44) \quad (0.46) \quad (0.05)
\]
As is seen from Equation 1, students who responded with a 5 to item Ext, are predicted to have self-efficacy scores 1.93 logits higher than their peers who responded with a 1 to the same item. Similarly, students with an A-grade achievement in maths are predicted to have self-efficacy scores that are 1.26 logits higher than their peers who achieved an E-grade. Although age is shown as a statistically significant predictor of self-efficacy in the model, it is not of practical significance, especially given that reported standard errors associated with self-efficacy scores have a mean of 0.47 logits.

A hierarchical linear model was also fitted to these data with a random component – based on teacher – included in the constant term. The inclusion of this random component was used to assess any dependence in the self-efficacy scores of students taught by the same teacher. Reported fixed effects for the model were as above. A gender term was included in order to detect any possible interaction between teacher and gender, but this was not significant. Based on a comparison of deviances test (Faraway, 2006), the hierarchical model reported significantly better
fit, at the 1% level, than the simple linear model. In relation to the random component of the model, the reported intra-class coefficient was 0.06, suggesting that teacher related factors such as social persuasion were minimal for this group, in that they contributed 6% of the variance in self-efficacy scores.

**Discussion**

The results suggest that the theoretical predicted sources of self-efficacy analysed in the study, namely: prior mastery experiences, the vicarious experiences of others, and social persuasion, contributed to these students self-efficacy in statistical literacy. Students who achieved an A-grade in mathematics were much more likely to display high levels of self-efficacy than those who achieved an E-grade. Similarly, students’ perceived mathematics ability with respect to their peers was a key predictor of their self-efficacy, whereas their perceived ability in mathematics with respect to other subjects was not, supporting the findings of Bong (1998). In addition to this, the hierarchical model suggested that teachers had a very small influence on their students’ self-efficacy, supporting the notion that social persuasion may have been a contributing factor. It was expected that prior achievement should have had a much stronger influence on self-efficacy than a factor assessing the vicarious experiences of others. Had prior achievement in statistics data been available, achievement may have been a much stronger predictor of self-efficacy than this frame specific self-concept. This lack of domain specific achievement data is a limitation of the study. It is also possible that some of the children were unfamiliar with the specific statistical tasks outlined in the instrument and had to rely on the vicarious experiences of their peers as a means of judging their own self-efficacy. Based on a review of the relevant state syllabus documents the tasks associated with each of the self-descriptions should have been encountered by all students. It is not certain, however, whether this actually occurred.

The expected influence of gender on self-efficacy in statistical literacy was not evident in any of the linear models. This result could suggest that the influences of male-dominated stereotypes in mathematics and female-dominated stereotypes in language (Hyde & Durik, 2005) may interact in the statistical literacy domain where students require both mathematical knowledge and language skills such as “explaining”. If true, the increased prominence of statistics in the mathematics curriculum may contribute to higher female participation rates in non-compulsory mathematics courses.

In regards to the primary/secondary transition, there was an observed drop in levels of self-efficacy, but this was not statistically significant, supporting the view that motivational states may be stable prior to this transition (Marcoulides et al., 2008). The reported drop in self-efficacy
between primary and secondary was at odds with the reported positive association between age and self-efficacy, suggesting that the age/self-efficacy relationship is actually curvilinear.

Despite the assertion by theorists that self-efficacy beliefs should be formed primarily from enactive mastery experiences (Bandura, 1997; Schunk, 1991), the results of the study suggest that the vicarious experiences of others – as reflected in the significant influence of a frame specific self-concept – may have a strong influence. This result has implications for teachers in that the self-efficacy of some students may be increased if the work of their more capable peers is used in classes as a model or exemplar.

Acknowledgements

Thanks are extended to Assoc. Prof. Rosemary Callingham, Prof. Ian Hay and Prof. Jane Watson for their kind assistance and advice. The research was funded by Australian Research Council grant number LP0669106, with support from the Australian Bureau of Statistics.

References


