Validation of an Assessment Instrument Developed for Eliciting Student Prior Learning in Graphing and Data Analysis

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This paper reports on the validation of an assessment instrument used to elicit student prior learning in relation to reasoning about data in an ICT environment. A paper-based assessment instrument developed using a theoretical framework about statistical thinking and reasoning in relation to data analysis, graphing, and graph-sense making was completed by year 4, 5, and 6 students. Student responses were analysed using the framework to determine if the assessment instrument elicited responses for all aspects of the framework. The results identified that one aspect of the framework had not been addressed; informing further development of the theoretical framework and changes to the assessment instrument.

In recent times, it has become apparent that evidence-based research has the potential to influence education policy and has a role to play in transforming educational practices (Slavin, 2002). This has resulted in the call for research to be scientific and rigorous in terms of scientific inquiry (Kalantzis, 2006). The National Research Council (2002) noted that there are a variety of scientific research designs utilised in education research and caution that the design of research does not necessarily make it scientific, noting:

> To be scientific, the design must allow direct, empirical investigation of the research question, account for the context in which the study is carried out, align with a conceptual framework, reflect careful and thorough reasoning, and disclose results to encourage debate in the scientific community. (p.6)

It is, therefore, pertinent at this time to select research methodologies that account for these ideas of scientific inquiry. It is also important to ensure the methodology uses theoretical frameworks to inform the research approach, provides the evidence required to answer the research questions, and determines if the data collection instruments employed provide the evidence required to ensure the results are valid and credible (Shavelson, Phillips, Towne, & Feuer, 2003) .

A review of the literature revealed three distinctive research methodologies that are considered evidence-based research. The first is based on traditional scientific experimental design. The second is based on qualitative research and is termed correlational and descriptive research and the third, design-based research, appears to be a combination of the first two. Of particular interest are the design-based research methods as they can provide a lens for understanding how theoretical claims about teaching and learning can be transformed into effective learning in educational settings (The Design-based Research Collective [DRC], 2003) and are characterised as being "iterative, process focused, interventionist, collaborative, multileveled, utility orientated, and theory driven" (Shavelson et al., 2003, p. 26). They are based on design-analysis-redesign cycles that move toward an understanding of learning and activity or artefact improvement. Importantly, they are theory driven as they test and advance theories through interrogation and repetition of design-analysis-redesign cycles and are particularly suited to the exploration of significant education problems within technology-based learning environments (Seeto & Herrington, 2006).

These principles of design-based research have been incorporated into a project investigating ways in which technology contributes to the development of statistical thinking and reasoning for students when using a data analysis program, *TinkerPlots Dynamic Data Exploration* (Konold & Miller, 2005). The purpose of the research was to explore aspects of the learning environment that contributed to students' development of statistical thinking and reasoning in an ICT environment, from an holistic perspective. Both qualitative and quantitative data were collected. Student interviews, researcher observations and reflections, student work samples, student survey, and video of teaching and learning episodes were used to collect evidence. Analysis of the data involved cluster analysis, and application of descriptive statistics (Miles & Huberman, 1994).

As part of the project, an assessment instrument was developed to evaluate student prior learning (Appendix A, Fitzallen, 2006). It was developed using a theoretical framework, *Model of graphing in an ICT environment* (Fitzallen, 2006), which was developed from theoretical models of statistical thinking and reasoning that were directly related to data analysis, in particular, graphing. It was also influenced heavily by the learning environment afforded by *TinkerPlots*.

This paper reports on the validation process undertaken to (a) put into action the design-based research methodology and (b) determine if the assessment instrument provided the empirical evidence expected.

Method

Participants. The participants for this part of the larger research project were drawn from a grade 4/5 class (n = 21) at a district high school (grades K – 10) and two grade 5/6 classes (n = 50) at a primary school (K-6). The schools were selected as they were in involved in an Australian Research Council Linkage Project, *Providing the Mathematical Foundation for an Innovative Australia within Reform-based Learning Environments* (MARBLE), which was a professional learning program. All students in the three classes completed the paper-based assessment instrument, which took approximately 45 minutes. Of the 71 students, one student from the grade 4/5 class withdrew participation in the research project. The assessment instrument collected from that student was returned to the classroom teacher and subsequently returned to the student.

Data Analysis. As the purpose of this paper is to validate the assessment instrument, quantitative data only will be analysed and reported in this paper. It should be noted that the student responses on the assessment instrument provided rich, descriptive information about their understanding of graphs and graph making. They provided valuable information about the prior learning of the students, which was used to plan the implementation of a learning intervention, designed to explore students' development of statistical thinking and reasoning in a technology environment. Qualitative analysis of the data was undertaken, informed changes to the assessment instrument, and will be reported elsewhere.

Results

It was anticipated that questions on the assessment instrument would address multiple categories of the theoretical framework used to construct the assessment instrument (Fitzallen, 2006). The shaded areas in Figure 1 indicate the connections between the theoretical framework and the assessment instrument items. The unshaded areas indicate when no data collection is anticipated for that key element. The shading is to assist in identifying easily the disparity between the anticipated data collection points and the actual data collection points. As the assessment instrument was a paper-based survey, the key element *Understanding how to use the features of technology* was not addressed in any of the questions. The assessment instrument included items that were similar to the data representations used in *TinkerPlots*.

The student responses were collated to determine a count of how many students provided information on the assessment instrument according to each of the key elements of the categories of the theoretical framework. At this stage, no qualitative analysis was conducted. The results are presented in Figure 1.

Category	Key elements	Item no.						
		1	2	3	4	5	6	7
Generic Knowledge	Speaking the language of graphs	29	17	7	32		63	51
	Recognising the components of data and graphs.	43	25	20	85	87	70	81
	Understanding how to use the features of technology.							
Being creative with data	Reducing data to graphical representations or statistical summaries.		93			4		
	Constructing different forms of graphs.		17					
	Translating verbal statements into graphs.							
Understanding data	Making sense of data and graphs.	5			60	10		51
	Understanding the relationship among tables, graphs, and data.	5					45	18
	Identifying the messages from the data.	1			7			20
	Answering questions about the data.							47
	Recognising appropriate use of different forms of graphs.	10	2	25	75		70	
	Describing data from graphs.	52	43	20				81
Thinking about data	Asking questions about the data.					87		
	Recognising the limitations of the data				15			
	Interpreting data and making causal inferences based on the data				20	2		15
	Looking for possible causes of variation					1		12
	Looking for relationships among variables in the data.					1		20
	No or inappropriate response	16	10	55	15	13	23	19

Figure 1. Percentages of responses provided according to each key element of the theoretical framework.

Discussion

The data presented in Figure 1 show clearly that the assessment instrument provided a great deal of information about students' prior knowledge of graphing. Although the data collected for this report are only a count of student responses for each key element, it was obvious from Figure 1 where there were gaps in the data. Of particular note is that there were no data collected for *Translating verbal statements into graphs* from any of the items on the assessment instrument. Examination of the assessment instrument in Appendix A revealed that there are no items requiring students to perform that task. It is recommended that an assessment item be developed to address this omission.

Another gap in the data was evident for item 4, for the category of *Being creative with data*. The item required students to construct a graph; therefore, it was inappropriate for that category to be highlighted for the item. The item required students to construct a graph based on the data in a table. Seventy percent of the students were able to draw a graph from the data, six students constructing covariation graphs. Most students produced bar graphs, many of which did not reflect the data appropriately.

Item 3 had the highest percentage of *no or inappropriate responses*, with 55 percent of the students stating that they had not used graphing software to create graphs. This item also required students to describe the type of graphs constructed, with only 20 percent of the students able to describe graphs constructed. Items 5 and 7 required students to read information from graphs and make inferences based on the graphs. The students were able to draw information from the graphs but had difficulty making inferences and determining the trend in the data.

Using the theoretical framework to analyse the data from the assessment instrument highlighted two aspects of the framework that required modification. The student responses to item 2 and 4 required students to reduce data to graphical representations; however, none of the items provided the opportunity to reduce data to statistical summaries. Based on this it is recommended that the key element *Reducing data to graphical representations or statistical summaries* be separated into two separate key elements. It also became apparent that the student responses related to *Describing data from graphs* only elicited low level responses and was more appropriately placed in the *Being creative with data* category. Figure 2 reflects these modifications to the original *Model of graphing in an ICT environment* (Fitzallen, 2006).

<table>
<tr><th colspan="2">Categories</th><th>Key Elements</th></tr>
<tr><td>Generic Knowlege</td><td rowspan="2">Being creative with data</td><td rowspan="2">Reducing data to graphical representations.
Summarising data.
Constructing different forms of graphs.
Translating verbal statements into graphs.
Describing data from graphs.</td></tr>
<tr><td rowspan="3">Speaking the language of graphs and data.
Recognising the components of data and graphs.
Understanding how to use the features of software and technology environments.</td></tr>
<tr><td>Understanding data</td><td>Making sense of data and graphs.
Understanding the relationship among tables, graphs, and data.
Identifying the messages from the data.
Answering questions about the data.
Recognising appropriate use of different forms of graphs.</td></tr>
<tr><td>Thinking about data</td><td>Asking questions about the data.
Recognising the limitations of the data.
Interpreting data and making causal inferences based on the data.
Looking for possible causes of variation.
Looking for relationships among variables in the data.</td></tr>
</table>

Figure 2. Adapted model of graphing in an ICT environment.

Conclusion

The changes proposed to the theoretical framework and the assessment instrument suggested in this paper were determined as part of the design-analysis-redesign cycle of the research project. Further analysis of the qualitative data from the student responses on the assessment instrument will be used to reiterate the design-analysis-redesign process. This may inform further development of the theoretical framework and suggest other changes to the assessment instrument, potentially strengthening the validation of the assessment instrument. In addition, the potential of applying the Rasch model (Bond & Fox, 2007) to the quantitative data to increase internal validity of the research project will be explored.

The results from the research reported in this paper provided empirical evidence that was used to plan a teaching and learning intervention to develop students' understanding of covariation using *TinkerPlots*. It was determined that the students had limited experience using graphing software to construct graphs; were experienced at reading individual data points; were less experienced at determining the trend in graphs or the messages in data; were inexperienced at describing graphs and the purpose of graphs; and previous experiences of constructing graphs were predominantly focused on bar graphs, with little experience using a variety of graph types.

The assessment instrument was designed so that the key elements were addressed on multiple occasions across the range of items in the instrument. On the whole, this was the case. It is, however, important to evaluate the responses to determine the range of level of responses to get an accurate picture of the statistical thinking and reasoning of the students in the study.

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Appendix A: *Assessment instrument items* (Reproduced from Fitzallen, 2006, pp. 207-208)

Item no.	Item description
1	What is a graph? What are graphs used for? Where have you seen graphs used?
2	Draw an example of a graph. Any type will do. Put as much detail on the graph as possible. What does the graph show?
3	Have you used the computer to draw graphs before? What programs did you use? Describe what sort of graphs you drew. What were the graphs used to show?

4

A science class was studying temperature. They used a thermometer to measure the room temperature every 5 minutes for 30 minutes.

First they turned a heater on for 15 minutes.
Next they turned the heater off for 10 minutes.
Lastly they opened the window for 5 minutes.

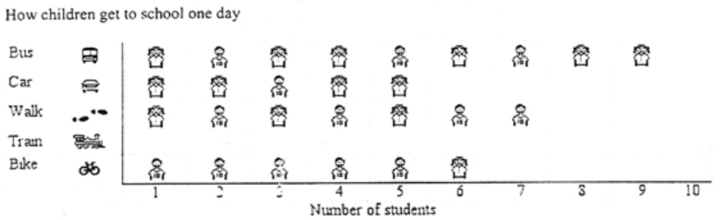
They wrote down these numbers.

Time (Minutes)	5	10	15	20	25	30
Temperature (°C)	15	20	25	25	25	15

Draw a graph to show how the temperature changed over time.

Moritz (2003b, p. 234).

5



a) How many children walk to school?
b) How many more children come by bus than by car?
c) Would the graph look the same everyday? Why or why not?
d) A new student came to school by car. Is the new student a boy or a girl? How do you know?
e) What does the row with the Train tell about how the children get to school?
f) Tom is not at school today. How do you think he will get to school tomorrow? Why?

Watson & Kelly (2003, p. 722).

6 The information about individual students is on separate cards, like the ones below. What questions about the group of students could be answered by using the information on the cards?

	Student 1	Student 2	Student 3
Gender	Male	Male	Female
Height	1.3m	1.3m	1.2m
Eye Colour	Blue	Brown	Brown
Hair Colour	Blonde	Brown	Brown

Adapted from Chick & Watson (2001).

7

Some students were doing a project on noise.

They visited 6 different classrooms. They measured the level of noise in the class with a sound meter. They counted the number of people in the class.

They used the numbers to draw this graph.

Q1. Pretend you are talking to someone who cannot see the graph. Write a sentence to tell them what the graph shows. “The graph shows...

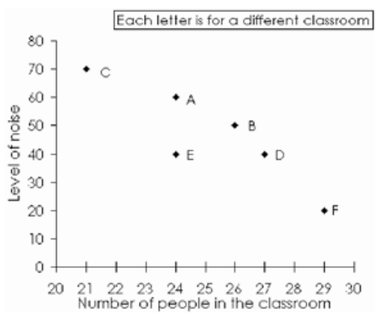
Q2. How many people are in Class D?

Q3. If the students went to another class with 23 people, how much noise do you think they would measure?

Please explain your answer.

Q4. Jill said, “The graph shows that classrooms with more people make less noise”. Do you think the graph is a good reason to say this?

❑ YES or ❑ NO Please explain your answer.



Moritz (2003, p. 525).