Do Map Drawing Styles Of Novice Programmers Predict Success in Programming? A Multi-national, Multi-institutional Study.

Denise Tolhurst
University of New South Wales, Australia

d.tolhurst@unsw.edu.au

Bob Baker
University of New South Wales, Australia

bob.baker@unsw.edu.au

John Hamer
University of Auckland, NZ

J.Hamer@cs.auckland.ac.nz

Ilona Box
University of Technology Sydney, Australia

ilona@it.uts.edu.au

Quintin Cutts
University of Glasgow, UK

quintin@dcs.gla.ac.uk

Michael de Raadt
University of Southern Queensland, Australia

deraadt@usq.edu.au

Sally Fincher
University of Kent, UK

S.A.Fincher@kent.ac.uk

Patricia Haden
Otago Polytechnic, NZ

phaden@tekotago.ac.nz

Margaret Hamilton
RMIT University, Australia

margaret.hamilton@rmit.edu.au

Raymond Lister
University of Technology Sydney, Australia

raymond@it.uts.edu.au

Marian Petre
Open University, UK

m.petre@open.ac.uk

Anthony Robins
University of Otago, NZ

anthony@cs.otago.ac.nz

Simon
University of Newcastle, Australia

simon@newcastle.edu.au

Ken Sutton
Southern Institute of Technology, NZ

ken.sutton@sit.ac.nz

Jodi Tutty
Charles Darwin University, Darwin, Australia

jodi.tutty@cdu.edu.au

Abstract

In this paper, we present the results of one aspect of a multinational, multi-institutional study of computer programming students. Specifically, this paper reports on an exploration of relationships between novice programmers' map-drawing styles (landmark, route or survey) and success in a first programming course at tertiary level. Relationships were found between map-drawing style and success of students in introductory programming courses, but there were mediating factors that resulted in some mixed findings between the countries in which data was collected. The results of this study identify some rich areas for further exploration, and suggests how this line of research might progress.

Keywords: Navigation, way-finding, introductory programming, novice programmers

1 Introduction

There is evidence that programmers use mental imagery when designing programs (Green, 1997), (Petre and Blackwell, 1999). In a study of expert programmers, Petre and Blackwell identify a variety of spatial metaphors used by programmers to capture the way they think about emerging solutions during the programming task. The experts studied reported using spatial

representations, for example the description of a problem space as a landscape:

> "…oh, that happens over there… it's on the horizon, so I can keep an eye on it, but I don't really need to know…" (p117)

Finding one's way in *information* space has been likened to way-finding and navigation in physical space. Metaphors of *getting lost*, *navigational* links, *hyperspace*, *disorientation*, moving *up* and *down* in text, information *landscapes*, and so on are now commonplace in the literature on hypertext and the World Wide Web (McKnight, Dillon and Richardson, 1991).

In the context of programming, program code has been characterised as a virtual space – a Codespace (Cox and Fisher, 2004; Cox, Fisher and O'Brien, 2005), and many of the problems that programmers face in navigating a Codespace have been likened to those encountered when navigating physical space. While developing and in understanding program code, the programmer has to locate code segments and to move between them. Cox and Fisher stress the importance of a structural view of a program – its layout and organisation – for being able to move around a Codespace.

In a study of Novice Programmers, Mosemann and Wiedenbeck (2001) investigated whether different program navigation methods would lead to differences in program comprehension, as characterised by Biggerstaff, Mitbander and Webster (1993);

> "A person understands a program when able to explain the program, its structure, its behaviour, its effects on its operational context, and its relationships to its application domain in terms that are qualitatively different from the tokens used to construct the source-code of the program."

Mosemann and Wiedenbeck (2001) hypothesized that a sequential flow strategy would lead to a fragmented bottom-up view of the program, whereas a control flow strategy would lead to a top-down, hierarchical view of a program. They found no significant difference between the two strategies on measures of program comprehension, and that novice programs were comfortable with both styles of navigation. They note that in spite of the sequential method being most natural for novice programmers, those that used a control flow strategy performed as well.

We were interested in finding whether these patterns of preferences for navigation strategies were reflected in map drawing tasks, and how these physical navigation strategies related to performance in a programming course.

1.1 Landmark, route, and survey knowledge

Werner et.al. (1997) suggest a hierarchy in acquisition of spatial knowledge, from *landmark* to *route* to *survey* knowledge, which they describe as follows;

> "Different forms and representations of spatial information can be identified in systems navigating in complex surroundings. One of the most common distinctions in spatial navigation research concerns the difference between landmark, route, and survey knowledge of an environment. Landmarks are unique objects at fixed locations, routes correspond to fixed sequences of locations as experienced in traversing a route; survey knowledge abstracts from specific sequences and integrates knowledge from different experiences into a single model."

A similar transitional model is suggested by Poucet (1997), who identifies three stages in building a survey representation:

1. A representation of place with local reference frames (landmarks)
2. Place representations are linked to together but retain local references (routes)
3. The reference frames for different places are changed to a common reference system (survey)

We used these distinctions as a basis for coding the maps produced in the mapping task, described below.

2 Method

2.1 Coding of the map-drawing data

A map-sketching exercise was designed to assess students' ability to articulate a simple familiar search and decision strategy effectively.

Participants were asked to carry out a mapping task in two phases; firstly to draw a map of a given area so that the researcher could get from one location to another. Participants were then asked to annotate the map with key decision points, explaining what a person using the map would need to do at the decision points. Students were given a differently coloured pen to add their annotations in the second phase.

Maps constructed in this activity were photographed or scanned electronically and the resulting images printed. These maps were then analysed for evidence one of one of the three broad navigation strategies of Landmark, Route or Survey.

Decisions about the strategy used by participants were based on identifying the following criteria in the participants' maps:

Landmark:

- the focus of the map is key visual landmarks (fountains, sculptures, notable buildings) which are given prominence
- landmarks are unique objects
- landmarks often exaggerated in size or distorted, or otherwise given prominence (e.g. labelling, bolder print)
- route moves from landmark to landmark

Route:

- the focus of the map is the actual route taken
- route takes prominence, often with a path identified by a line or written directions on the map

- features on the route are identified

Survey:

- the map focuses on an overview of the area surrounding the route and includes detail beyond the route
- there is a focus on overall structure of the area
- may include compass points
- may not have the route drawn on, or the route is not prominent
- shows integrated knowledge of the area

Samples of map-styles and key characteristics follow.

2.1.1 Example of a landmark map

The map in Figure 1 was characterised as using a landmark map-drawing strategy because the route is predominately identified by key landmarks on the route, for example: 'big square cube thing', 'cobblestone path', traffic lights', etc. The focus of the map is these landmarks.
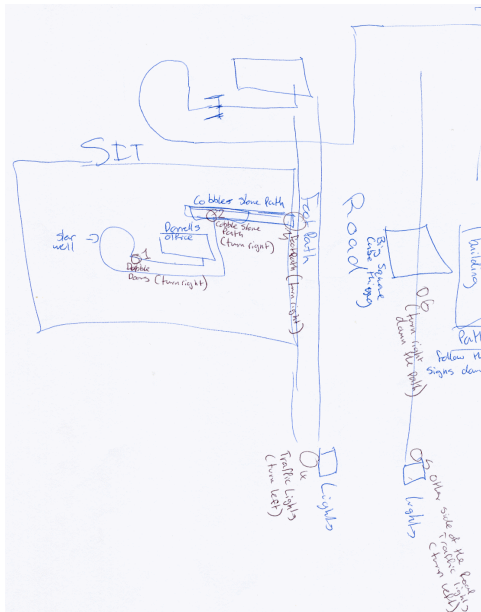

Figure 1 Example of a 'landmark' map-drawing strategy

2.1.2 Example of a route map

The map in Figure 2 was characterised as using a route map-drawing strategy because the route is predominately identified by a path from the beginning to destination. The focus is on the route, with little detail provided of the surrounding area. Some landmarks are evident (the Botanical garden for example) the focus of the map is on the path to be taken.
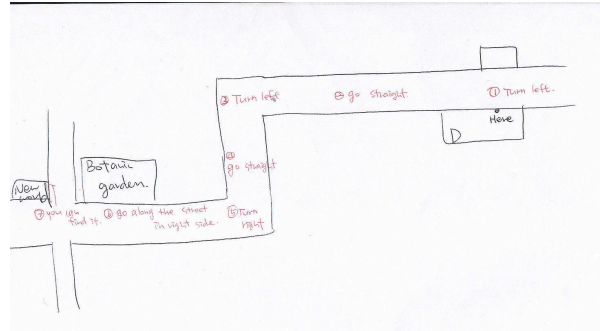

Figure 2: Example of a 'route' map-drawing strategy

2.1.3 Example of a survey map

The map in Figure 3 was characterised as using a survey map-drawing strategy because the map predominately includes a survey of the surrounding area to the route. Detail goes beyond the path for the route, providing 'survey' information for orientation. This map shows survey information around the route to get to the required building, and also survey information of the building.
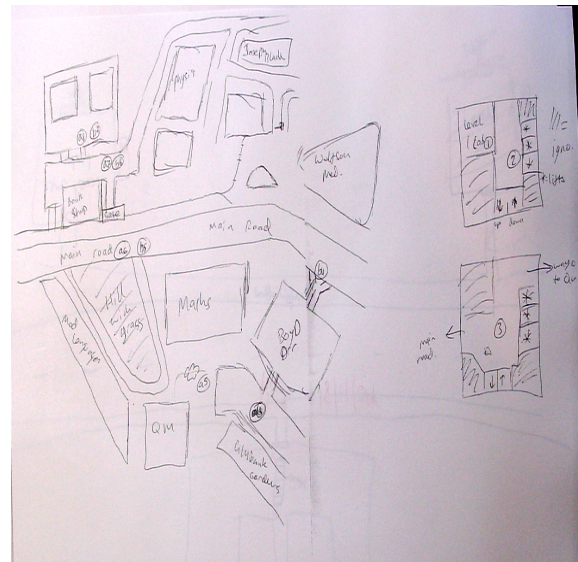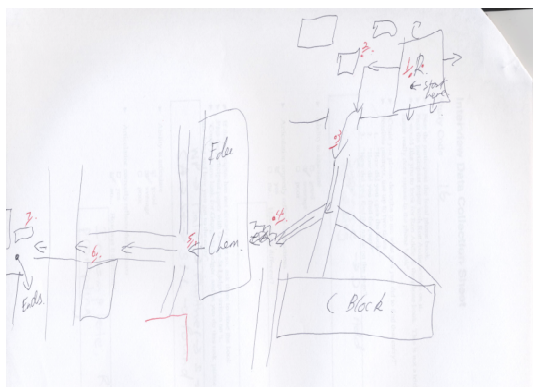

Figure 3: Example of a 'survey' map-drawing strategy

2.2 Strategy identification problems

While some students' maps could be clearly identified as using either landmark, route or survey strategy (as shown in the figures above), some maps were difficult to identify as using just one clear strategy. Some maps appeared to include features from two different strategies, for example: a map that provided route information, but also included traces of survey data on the edges of the route. Such survey information was minimal, but did go beyond the focus on the route. An example of a map that provided such problems is shown in Figure 4.
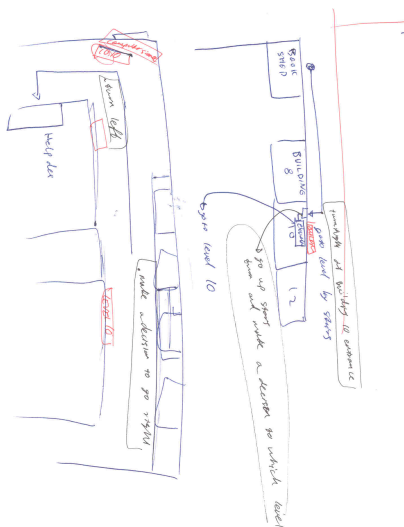
2.3 Map-drawing strategy limited by physical environment

Some institution locations were such that the physical environment limited students to drawing maps that could make little use of landmarks and had little scope for providing survey information. These locations did not allow students to draw detailed orienting information that was indicative of a survey strategy. Such an institution was a campus based in a high-rise building, in a street of high-rise buildings that had a visually consistent streetscape. The task that students were effectively reduced to in this locations was 'maze-running', which provided no scope for including landmark information or survey detail. An example of a map from this campus is shown in Figure 5.

Figure 4: Sample of map that provided difficulties in coding – map-drawing strategy with features of both route and survey.

The strategy to overcome the first issue, of difficulty in coding some maps, is described in the following section. Analysis was carried out on the data for all institutions, with some further analysis excluding data from those institutions where participants were restricted in the map-drawing strategies they were able to use, due to the nature of the environment they were sketching.

Figure 5 Sample of map that provided difficulties in coding – map-drawing strategy limited by physical environment of city streets and high-rise building.

2.4 Coding of maps for reliability

Two researchers worked together on one data set and developed a coding scheme to identify the mapping strategies (landmark, route and survey). This scheme was trialled on another set of data for one institution and refined to the scheme described above in the introduction. The two researchers then independently coded the remaining maps as landmark, route and survey. The codes from the two researchers were compared with a reliability of 76% (with removal of the data for the institutions whose physical environments that caused problems, as described above). A third researcher then considered the codes that were anomalous. Ultimately the three researchers reached consensus on the final coding of the maps with originally anomalous coding.

2.5 Measurement of programming success

Final marks in the respective courses of study were taken as measures of success in introductory programming. The method of assessment in each course was determined by each institution involved and there was no assessment approach defined by the study.

3 RESULTS

3.1 Descriptive Statistics

Basic descriptive statistics were calculated using SPSS V11.0 for each institution.

Table 1 shows means, Ns, and standard deviations as a total for each institution, and also divided according to map-drawing strategies of landmark, route and survey.

3.2 Analyses of variances

Analyses of variance using the software package SuperANOVA 1.11 indicate some statistically significant differences in the map-drawing strategies for some variables. It should be noted however that there are uneven cell-sizes for the comparison groups (see Table 1). For this reason the following ANOVA results should be interpreted cautiously.

3.2.1 Two-way analysis of variance of marks based on map style and country

Table 2 shows the results on a two-way analysis of variance of marks based on map style and country, indicating a significant interaction ($p=.02$) between the two variables.

Institution	Mapstyles, Totals (and missing maps)	Mean	N	Standard deviation
All	Missing maps	41.0	32	25.0
	Landmark	54.7	15	27.7
	Route	64.7	84	21.0
	Survey	64.2	35	27.0
	Total	59.1	166	25.3
A	Landmark	8.0	1	-
	Route	57.7	6	34.0
	Survey	69.0	7	26.9
	Total	59.7	14	32.1
B	Landmark	-	0	-
	Route	53.8	6	13.2
	Survey	94	2	8.5
	Total	63.8	8	22.0
E	Landmark	64.0	2	24.0
	Route	64.6	5	17.4
	Survey	69.2	6	19.3
	Total	67.0	13	17.6
F	Landmark	78	1	-
	Route	60.0	8	18.2
	Survey	-	0	-
	Total	61.8	9	18.1
H	Landmark	-	0	-
	Route	76.1	11	14.2
	Survey	90.5	2	2.1
	Total	78.3	13	14.1
I	Missing maps	41.0	32	25.0
	Landmark	64.5	3	27.1
	Route	67.9	13	18.4
	Survey	56.8	4	38.8
	Total	50.31	52	27.0
J	Landmark	-	0	-
	Route	70.3	12	27.0
	Survey	83.0	2	5.7
	Total	71.4	14	25.3
K	Landmark	73.0	1	-
	Route	58.5	8	26.4
	Survey	62.0	1	-
	Total	60.0	10	23.7
M	Landmark	37.7	3	7.8
	Route	57.0	6	18.2
	Survey	56.0	2	46.7
	Total	51.6	11	21.8
N	Landmark	10.0	1	-
	Route	64.8	5	11.2
	Survey	77.0	1	-
	Total	58.7	7	23.8
P	Landmark	72.3	3	24.7
	Route	65.8	5	18.7
	Survey	41.9	8	20.6
	Total	55.1	16	23.7

Note: There are no missing maps for participants at institutions unless otherwise stated.

Table 1 Means, number and standard deviations of final marks for each institution by map-drawing strategy, totals and missing maps

| Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Country	2	119.340	59.670	.115	.8911
MapStyle	2	731.465	365.733	.708	.4948
Country * MapStyle	4	6205.512	1551.378	3.002	.0210
Residual	125	64608.441	516.868		

Dependent: Mark

Table 2: Results of ANOVA of marks for the variables mapstyle and country

Trends in the map-drawing strategies adopted by students in each institution are shown in the box-plots in Figures 4.1 to 4.13. Figure 4.1 shows the box-plot for all institutions, and Figure 4.2 shows a box-plot for all institutions except the two institutions that were problematic to code (as discussed in section 2.4).
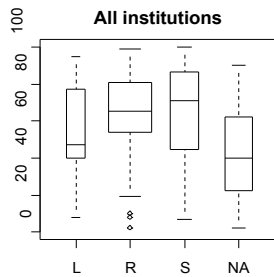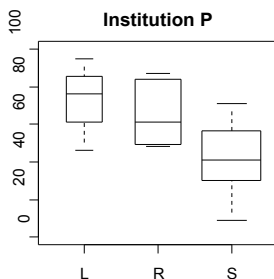

Figure 4.1 Box-plot of map-drawing strategies for all institutions
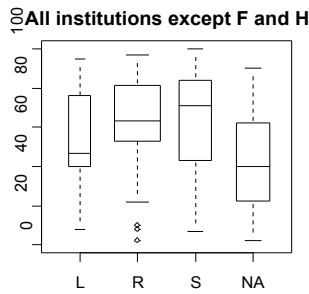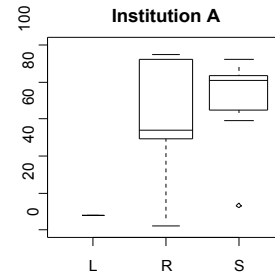

Figure 4.2 Box-plot of map-drawing strategies for all institutions, except F and H

Figure 4.3 shows the box-plot for the one United Kingdom institution involved in the study, indicating a trend in which students who draw maps focusing on landmarks gain higher overall final marks, students who draw route maps gain the middle marks in the cohort and students who draw survey maps gain overall lower marks.
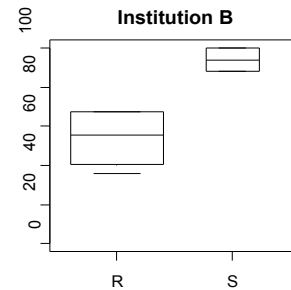

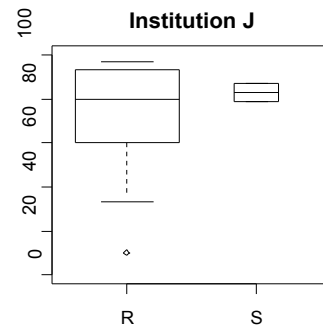**Figure 4.3 Box-plot of map-drawing strategies for United Kingdom institution P**

Figures 4.4 to 4.7 show the box plots for institutions in New Zealand. The box-plots for these institutions indicate a trend in the opposite direction to those found in the United Kingdom institution. Students drawing maps focussing on survey style gain highest marks, while those using a landmark style gain lowest marks.
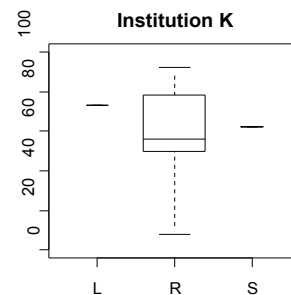

Figure 4.4 Box-plot of map-drawing strategies for New Zealand institution A

Figure 4.5 Box-plot of map-drawing strategies for New Zealand institution B

Figure 4.6 Box-plot of map-drawing strategies for New Zealand institution J

Figure 4.7 Box-plot of map-drawing strategies for New Zealand institution K

Box-plots for the Australian institutions, Figures 4.8 to 4.13, show a trend consistent to that found in the New Zealand institutions, but not as strong.
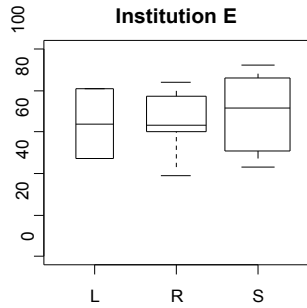

Figure 4.8 Box-plot of map-drawing strategies for Australian institution E
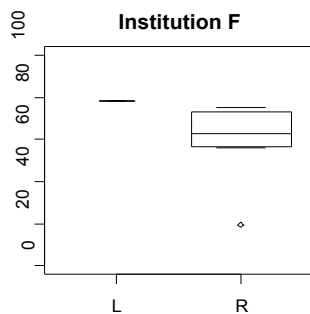

Figure 4.9 Box-plot of map-drawing strategies for Australian institution F
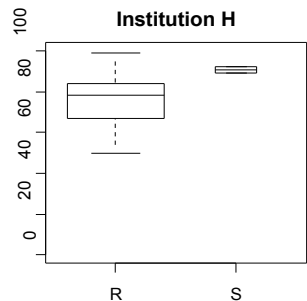

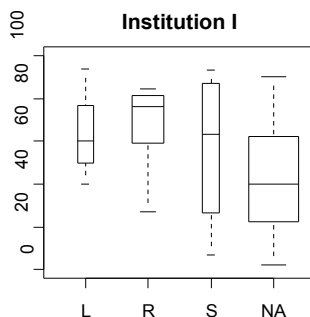**Figure 4.10 Box-plot of map-drawing strategies for Australian institution H**

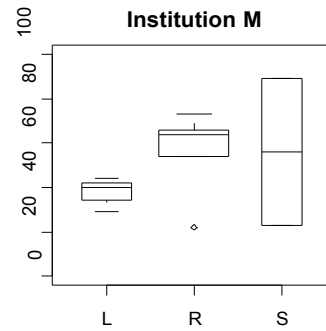**Figure 4.11 Box-plot of map-drawing strategies for Australian institution I**

Figure 4.12 Box-plot of map-drawing strategies for Australian institution M
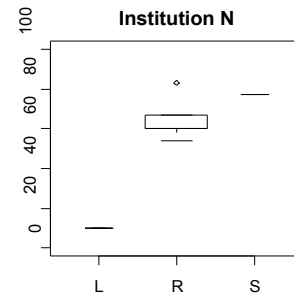

**Figure 4.13 Box-plot of map-drawing strategies for Australian institution**

Means for each of the groups, together with the cell-sizes for the groups are shown in Table 3. The variation in cell-sizes should be noted by the reader.

Means Table
Effect: Country * MapStyle
Dependent: Mark

	Count	Mean	Std. Dev.	Std. Error
NZ, S	12	74.917	22.781	6.576
NZ, R	31	61.798	26.463	4.753
NZ, L	2	40.500	45.962	32.500
A, S	15	67.480	27.310	7.051
A, R	48	66.401	17.123	2.471
A, L	10	52.250	25.770	8.149
UK, S	8	41.875	20.553	7.266
UK, R	5	65.800	18.727	8.375
UK, L	3	72.333	24.705	14.263

Table 3 Means, counts, standard deviations and standard errors for each cell in the ANOVA based on map style and country

A plot of the interaction between the variables mapstyle and country is shown in Figure 5. This plot indicates that the trend for students in the United Kingdom institution to gain higher marks when adopting a landmark map-drawing strategy is the opposite in New Zealand and the Australia. Students from Australia and New Zealand who draw survey-based maps are more strongly linked to higher final marks. This result is consistent with the results in the previous section on descriptive statistics, and while they indicate statistical significance, the uneven cell-sizes suggest that these results should be interpreted as an interesting trend worthy of further investigation.
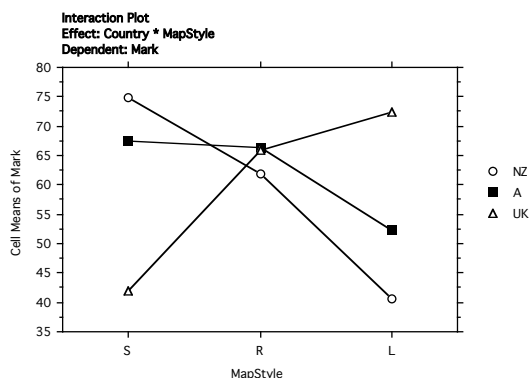
Figure 5 Plot of interaction between students' map-drawing style and country of institution in which students is studying.

3.2.2 ANOVA of map style and student descriptions of decision points

Analyses of variance were undertaken to detect differences between the map-drawing styles students adopted (landmark, route, survey) and the descriptions they used for decision points in the map-drawing exercise. Student descriptions of decision points were categorised as being based on environmental factors (what a feature looked like; e.g., large tree, big red building, etc.), as functional descriptors (in terms of the function of a building; e.g., a car-park, a coffee shop rather than the name of a feature), as a label (giving a name of a building, street, etc.), and other types of description. These categorisations were then calculated as a percentage of the total number of decision points offered by a student. Tables 4 and 5 show the results of analysis of variance based on map style and students use of environmental and functions descriptors, respectively. These ANOVAs indicate statistically significant differences between map style and environmental descriptions (p=.04) and between map style and functional descriptors (p=.02). No significant differences were found for other decision-point descriptors (label and other).

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
MapStyle	2	.599	.300	3.213	.0438
Residual	118	11.001	.093		

Dependent: envp

Table 4 Results of ANOVA for the variables mapstyle and proportion of environmental descriptors of decision points

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
MapStyle	2	.500	.250	3.873	.0235
Residual	118	7.615	.065		

Dependent: funp

Table 5 Results of ANOVA for variables mapstyle & proportion of student functional descriptors of decision points

Means for each of the groups, together with the cell-sizes for the groups are shown in Table 6 and Table 7. Variations in cell-sizes should be noted by the reader.

Means Table
Effect: MapStyle
Dependent: envp

	Count	Mean	Std. Dev.	Std. Error
S	35	.609	.286	.048
R	72	.480	.321	.038
L	14	.652	.265	.071

Table 6 Means, counts, standard deviations & standard errors for each cell in the ANOVA based on map style and proportion of student environmental descriptors of decision points

Means Table
Effect: MapStyle
Dependent: funp

	Count	Mean	Std. Dev.	Std. Error
S	35	.195	.208	.035
R	72	.310	.278	.033
L	14	.149	.227	.061

Table 7 Means, counts, standard deviations & standard errors for each cell in the ANOVA based on mapstyle & proportion of student functional descriptors of decision points

Figures 6 and 7 show respectively the plots for the mean percentage of environmental and functional descriptors used by students organised according to map-drawing style adopted. In comparing the two plots, it is interesting to note the trends are reversed.

4 Discussion

There is a general trend for students who drew a survey map to gain higher marks than those who drew a route map, who in turn do better than those who drew landmark maps. We refer to this as the "L-R-S" trend. This trend mirrors the hierarchy of spatial knowledge described above Werner (1997), Poucet (1993). These parallels suggest that our participants do have preferred navigational strategies, and that these strategies are relevant to success in an introductory programming course.
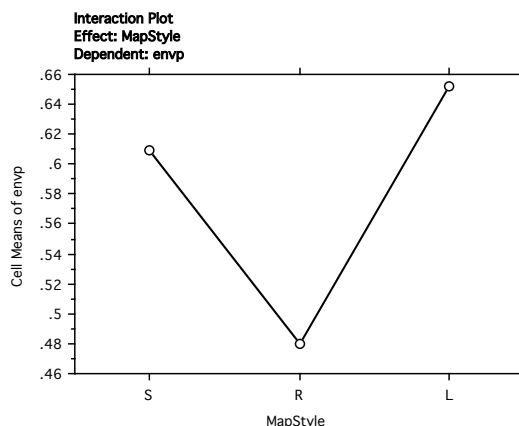
Figure 6: Plot of the proportion of environmental descriptors used by students organised according to map-drawing style.
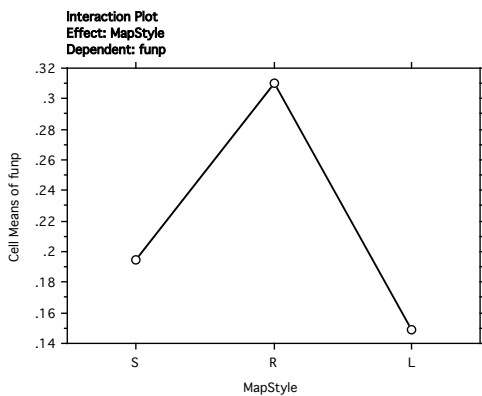
Figure 7 Plot of the proportion of functional descriptors used by students organised according to map-drawing style.

How these are relevant is a matter for conjecture at this stage, but the literature reviewed briefly above suggests that different navigational strategies may affect the way in which programmers are able to navigate programming code and to form a conceptualisation of the major features of this code in so doing.

The grouped results for the United Kingdom, New Zealand and Australia (see Figure 4.14) show an interaction-effect between country and mapping style. The differences in cell size means the interpretation of this result must be treated with caution. If we accept that there is an effect, we cannot tell whether this is due to general educational effects, the nature of the courses in each country, or the components used to determine the final mark for each course. The reasons for differences in the results for these countries require further investigation.

Although a significant relationship was found between descriptions of Decision Points given by participants and their map style (see Tables 4 and 5), these Decision Point descriptors were not related to final marks. This suggests that students' ability to represent navigational knowledge visually may not be related to their ability to describe it. There are some potential implications here for the use of written examinations over practical examinations, in capturing students' comprehension and creation of program structures.

In a study that included an examination of program design representations (Fincher, Petre, et.al., 2004) it was found that first competency (novice) students tended to rely on more textual representations, educators (more expert programmers) frequently employed diagrammatic representations and graduating students were evenly distributed among textual, graphical and standard diagrammatical representations. These variations in experience and representation method may have some correlation with the route, landmark and survey representations found in this study. Future studies could compare students' map-drawing strategies and compare them to program representation strategies to help identify a predictor for successful program design.

Problems associated with the coding of some maps as being landmark, route or survey could be attributable to the fact that students were not using one strategy exclusively. Student may have been conceptually using a mixture of approaches to develop their maps, which resulted in their maps exhibiting features of more than one approach. Attempting to code as exhibiting 'pure' approaches may not have been appropriate.

There are three confounding factors that may have contributed to the lack of any conclusive findings. Firstly, we did not assess the degree of environmental support given to navigation in the physical environment, such as campus maps and directional signs. Exposure to navigational support in the physical environments may have influenced the map-drawing approach taken by students. A second confounding factor is that the differences in the physical environments for which the maps were drawn. We speculate that the difficulty with these maps is due to the "maze-like" nature of the route sketched, principally through building corridors. Navigation in mazes is known to involve different navigational approaches (Werner, 1997). Future studies that explore map-drawing approaches should ensure that a given task is not maze-following.

The third potentially confounding factor in this study is the nature of the assessment strategies used to determine final marks. As these were not standardised across the institutions involved in this study there is potential for differences found to be attributable to differences in assessment strategy. Assessment approaches could include tasks such as: actual program design and coding tasks; tasks that require students to express conceptual understanding of program control-structures; written exams; practical exams; or, multiple choice questions. Future studies should be structured so that the assessment tasks are designed to measure higher-order skills and are consistent across institutions.

There are also some other potentially fruitful directions for future research. In addition to previously mentioned possibilities of further exploration of differences between countries and exploration of any predictive link between map-drawing strategies and representation of program designs, other research could include a number of possibilities. The most obvious of these is to repeat the research, but to include controls for the factors identified as confounding in this study.

We believe that it would also be informative to include in any future students the capture of information that exposes the sequence in which students constructed their maps. Video or graphic-tablet capture of the map-construction sequence may expose indicators of the conceptualisation that students have of the task. Whether students lay down survey information and then indicate a route, or describe a path and then add survey or landmark information as elaboration. Sequence of map construction would, we believe, provide richer information about students' cognitive processes.

In conclusion, this study identified trends, relating map-sketching styles to performance in an introductory programming course. We speculate that a students' ability to move through abstract information spaces, recognizing the major features or landmarks in those spaces is related to success in program comprehension and creation. These

are the same skills used in physical navigation tasks.

We feel that further investigation of the relationship between students' map-drawing style and success in computer programming is warranted.

6   References

Biggerstaff, T. J., Mitbander, B. G., and Webster, D. (1993). *The concept assignment problem in program understanding*. Paper presented at the 15th International conference on Software Engineering, Baltimore, Maryland.

Cox, A., Fisher, M. and O'Brien, P. (2005) Theoretical considerations on navigating codespace with spatial cognition. Romero, P., Good, J., Acosta Chaparro, E. and Bryant, S. (eds) 17th Workshop of the Psychology pf Programming Interest Group, Sussex University, June 2005. 92-105.

Cox, A., & Fisher, M. (2004). *Navigating codespace: A new direction for spatial cognition research*. Paper presented at the International Society for Human Ethology.

Fincher, S., Baker, B., Box, I., Cutts, Q., de Raadt, M., Haden, P., Hamer, J., Hamilton, M., Lister, R., Petre, M., Robins, A., Simon, Sutton, K., Tolhurst, D., Tutty, J. Programmed to succeed?: a multi-national, multiinstitutional study of introductory programming courses (2005). *Computing Laboratory Technical Report 1-05*, University of Kent, Canterbury, UK.

Fincher, S, Petre, M. Tenenberg, J. Blaha, K., Bouvier, D. Chen, T-Y., Chinn, D., Cooper, S., Eckerdal, A., Johnson, H., McCartney, R., Monge, A., Mostrom. J. E., Powers, K., Ratcliffe, M., Robins, A., Sanders, D., Schwartzman, L., Simon, B., Stoker, C., Tew A. E. and VanDeGrift, T. (2004) *Cause for Alarm? A multi-national, multi-institutional study of student-generated software designs*. Technical Report No. 16-04, Computing Laboratory, University of Kent.

Green, T. R. G. (1997). *Cognitive approaches to software comprehension: results, gaps and limitations*. Paper presented at the Experimental Psychology in Software Comprehension Studies, Limerick, Ireland.

McKnight, C., Dillon, A., and Richardson, J. (1991). *Hypertext in Context*. Cambridge, UK. Cambridge University Press.

Mosemann, R., and Wiedenbeck, S. (2001). *Navigation and comprehension of programs by novice programmers*. Paper presented at the EEE 9th International Workshop on Program Comprehension (IWPC 2001).

Petre, M., & Blackwell, A. F. (1999). Mental imagery in program design and visual programming. *International Journal of Human-Computer Studies, 51*(1), 7-30.

Poucet, B. (1993). Spatial cognitive maps in animals: New hypotheses on their structure and neural mechanisms. *Psychological Review, 100*, 163-182.

Werner, S., Krieg-Bruckner, B., Mallot, H. A., Schweizer, K., & Freksa, C. (1997). *Spatial cognition: The role of landmark, route, and survey knowledge in human and robot navigation*. Paper presented at the Informatik Aktuell (Informatik 97), Berlin.