BRACE

Building Research in Australasian Computing Education

The Experiment Kit

Experiment Kit: TOC

1. Question Formulation

General research question

This kit addresses factors that might influence entry-level undergraduate students' success in learning programming.

Learning to program is problematic, but our understanding of what makes it problematic is patchy and poorly integrated. Students display varying success in learning to program, but we have few (if any) reliable indicators of programming ability and performance. Among those suggested in the literature are: mastery of one's native language – the ability to communicate clearly and effectively both in speech and in writing, number of programming languages used or examined, spatial reasoning and mathematical ability, musical ability, and logical reasoning ability. The evidence for each is limited. Measures of general intelligence correlate well (Mayer, Dyck & Vilberg, 1989): the strongest evidence is that self-predicted success, attitude, "keen-ness" and general academic motivation indicate success in programming courses (Petre et al, 1989, Roddan, 2002, Rountree et al, 2002). However, this does not distinguish programming from any other subject, and has such a large effect that it may mask more subtle, disciplinary-specific, indicators.

Moreover, Computing does not have an agreed, established 'core' list of essential programming concepts, much less any robust instruments for assessing students' acquisition of programming concepts – or their acquisition of misconceptions, certainly nothing comparable to the 'Force Concepts Inventory' in Physics (Hestenes et al, 1992, Nasr et al, 2003).

Therefore, this kit uses four different diagnostics – attitudinal, cognitive, and behavioural – in an attempt to tease out (or possibly eliminate) factors that might relate to early programming performance: Biggs's Study Process Questionnaire (approaches to learning and study), a paper folding test (spatial visualisation and reasoning), and descriptions of common-place search and definition tasks (articulation of strategies).

Study's focal questions:

The study is in three parts:

i) Are there identifiable aspects of *approaches to study* that correlate to early programming performance?

ii) Does performance on a *spatial visualisation and reasoning* test correlate to early programming performance?

iii) Does students' ability to *articulate their strategies* for common-place search tasks correlate to early programming performance?

Subsidiary queries:

Are there differences displayed in differing sub-populations, such as:

- male students?
- female students?
- mature students?
- students exposed to different first programming languages or paradigms?
- students exposed to different instructional approaches?

Study's approach:

This study examines students' performance on four diagnostic tasks:

i) The *Biggs Study Process Questionnaire* derives from the notion that students' perceptions and learning activities are central to learning. An 'approach to learning' encompasses the relationship

between student, context, and task (Biggs et al, 2001). The revised questionnaire assesses deep and surface approaches to learning in a given context.

ii) The *Paper Folding Test* (VZ-2) is from the ETS Kit of Referenced Tests for Cognitive Factors (Ekstrom et al, 1976). The test is designed to measure visualisation and spatial reasoning, based on the ability to manipulate and transform spatial patterns, and hence to recognise whether one image is a transformation of another. In this case, subjects identify which pattern of holes would result in an unfolded sheet of paper after holes are punched through an arrangement of folds.

iii) The *description of a phone book search* and *sketch-map* are drawn from classroom practice and a tradition in CS education that uses common-place examples to convey programming concepts and make them relevant to students (Curzon, 2002). The tasks assess students' ability to articulate a simple and familiar search and decision strategy accurately.

Results of each of these diagnostics are then compared to students' performance on entry-level courses, as indicated by their grades.

Key Assumption:

That grades achieved in an introductory programming course are correlated to, and accurately reflect, a student's ability to program.

Limitations:

We are using just four diagnostics, from three perspectives. This is a study of limited scope and applicability.

Justification of approach:

- **Paradigm independence**
  The use of diverse and generalised stimuli makes the tasks paradigm independent, so that comparisons can be made across paradigms, languages, and pedagogic styles.

- **Triangulation**
  The study combines different approaches and collects both qualitative and quantitative data, in order to provide opportunities to contradict or corroborate within the study, by comparing the different data.

- **Building on existing work**
  This study is, in part, replicative, building on previous work for which there is standardised data available.

- **Scale**
  The quantity of institutions means that the number of participants recruited is at a scale unusual in the literature.

2a Data collection specification

For each institution:

- Characterise your context. This should include:
    - type of institution (e.g., university, liberal arts college, polytechnic, community college, etc.)
    - characterisation of intake (e.g., entrance requirements, students' focus, age range, etc.)
    - instructional structure of the course(s) (e.g., do they have labs) and
    - pedagogic structure of the course(s) (e.g. breadth first, uses an environment e.g. BlueJ, objects-first etc.).
- Characterise the paradigm you teach in for the first course in 2004
- Identify your institution code, which will part of the study code for each student. If you use subjects from another institution, please request an additional code.

Collection of background data:

You need access to students' academic records.
If you need to recruit subjects from another institution, you will need a collaborating academic within that institution. Work with the academic ***early*** to complete Human Subjects Approval at that institution.

For all students, from their academic records:

- Record grade on "introductory programming" course.
- Note the point at which you administer the tasks (week number into academic year, thus 14/26 is the 14th week of the academic year – or, in the University of Kent calendar, the first week of the second semester). Similarly, note the point at which you administer Biggs Study Process Questionnaire.
- Assign each subject a unique identifier of the form: 01 (Student 01), appended to your institution code (thus the first subject for Newcastle University would be E01).

Data collection from subjects:

Data Collection Overview:

1. Before – well before – the start of semester, complete Human Subjects Approval.
2. Within the first few weeks of the "Introductory Programming" course, administer the Paper-Folding Test and the Map-Sketch and Phone Book tasks to at least 15 students (see below).
3. Towards (or at) the end of the "Introductory Programming" course, administer to the same students (if still enrolled) the Study Process Questionnaire (note OCR opportunities). You may like to consider using `http://www.surveymaker.com.au` which has the SPQ already online.

Minimum data collection:

- Complete data on 10 students from "Introductory Programming" (or equivalent). 10 is a minimum requirement: 15 or 20 would be better.

Because of natural attrition, and because the study requires data collection at two separate points within the course, these minimum figures are *residual*: that is, remaining at the end of the study. You will have to gather initial data on more students (probably 50% more) to be assured of being left with sufficient students to complete the data collection.

Time allowance:

- Allow around ten minutes for the completion of the preliminary forms (human subjects and background questionnaire).
- Allow a maximum of forty five minutes per subject for the tasks. All of our pilot subjects completed the tasks within half an hour, but it's safer to leave a margin.
- You will also need to take the time to label all your materials (tapes, notes, subjects' responses) carefully, and to write down any extra observations that strike you at the time, so allowing forty five minutes in total will give you some margin for this.
- At the end of their programming course, separately administer the Study Process Questionnaire.

2b Details/phrases that may be useful with regard to Human Subjects Approval forms

This research is part of an international, multi-site project to investigate possible indicators of success in Computing. The subjects will be taking an introductory programming course. Each subject will be asked to complete:

- the Biggs Study Process Questionnaire
- a test of spatial visualisation and reasoning from the ETS Kit of Factor-Referenced Cognitive Tests
- two "everyday" behavioural tasks to elicit pre-algorithmic thinking.

These tasks, together, should take *circa* one hour. During the sessions, data arising from the Questionnaire and Cognitive Test will be captured on paper; data arising from the behavioural tasks will be captured by written notes and audio recording.

Subjects will be drawn from students enrolled in an introductory programming course. Their age range will be 18-65.

Personal data – age, gender, institution and academic grades – will be associated with the elicited material. The name (or other identifiable data, such as student number) of participants will be known to internal investigators, but will not be stored or made available to researchers outside of this institution.

RESEARCH SUBJECTS' INFORMATION SHEET

You have been asked to participate as a subject in a study that is part of a multi-site international research project investigating factors effecting success in computing. This research is designed to investigate students' attitudes and abilities over a range of tasks. You will be asked to complete a visualisation test and to undertake, and describe, two "everyday" tasks. These will, together, take *circa* forty-five minutes. During the exercises, we will take notes, and ask that we may tape-record the session. At the end of the semester, you will be asked to complete a questionnaire.

Some personal data – your age, gender, institution and academic achievement – will be associated with the task materials. However, neither your name (nor any other identifiable data, such as student number) will be stored after the data collection is complete, nor made available to researchers outside of this institution. All data gathered will be used solely for the purposes of this research project.

You may obtain answers to any pertinent questions about this research by telephoning <insert name> on <insert telephone number>_during the following times: <insert availability>

If you decide not to participate, your refusal will involve **no** penalty and **no** loss of benefits to which you are otherwise entitled.

Participation in this study is voluntary, and you may withdraw your consent to participate at any time without penalty.

You have the right to receive a copy of any consent form that you sign and of any written consent documentation information that is used in obtaining your consent.

In order not to bias subsequent interviews, please do not discuss details of the tasks with other students.

Human Subjects Research Consent Form

Letter of Informed Consent

I, (print name in full) _____ am a student registered at <insert name of institution>. In signing this consent form, I agree to volunteer in the research project being conducted by <insert your name here> between <enter dates here>. I understand that the research being conducted relates to possible indicators of success for computing. I understand that data from the tasks I complete will be used in aggregate, and that excerpts from tape-recorded verbal communications with the researcher will be studied and may be quoted in papers, journal articles and books that may be written by the researchers.

I grant authorization for the use of the above information with the full understanding that my anonymity and confidentiality will be preserved at all times. I understand that my name or other identifying information will never be disclosed or referenced in any way in any written or verbal context.

I understand that my participation is entirely voluntary and that I may withdraw my permission to participate in this study without explanation at any point up to and including, the last day of December 2004.

Signature
Date

2c Background questionnaire

- Study Code:
- Age:
- Gender:
- Program enrolled in (with major, if known):

Programming Experience

On a scale of 1 (never used) to 5 (have used a lot) please rate your familiarity with the following programming languages. For "other", please indicate specific additional languages.

Please indicate if you have had formal instruction any of these, and for how long (1 semester, a year etc.).

	1	2	3	4	5	Formal instruction?
Java						
C++						
C						
Ada						
Scheme						
Pascal						
Visual Basic (VB)						
Other languages. Please specify each on a separate row						

2d Specification of setup

You should make sure you conduct the experiment in a quiet room, where you will not be disturbed. Make sure you have:

- Human Subjects' Information Sheet and 2 copies of the Consent Form (one for them and one for you)
- The background questionnaire
- A copy of the paper-folding task
- Descriptions of two walking journeys which have 8-10 decision points.
- A working tape recorder
- Enough tapes & batteries
- Pens and pencils (in several colours)
- A supply of plain, blank paper
- Sticky tape
- The telephone directory. Have two searches prepared, with the names written on paper. The second name should be a patronymic surname and include another rule: for example Mac/Mc or Van or Ben. Chose one that is plentiful in your geographic area.
- If there isn't a clock in the room, make sure you take a watch with a second hand

Sit so that you can see the subject (and the subject can see you!). Side by side, or across the corner of a desk is probably better than face to face across a table. It's fine – sometimes reassuring – for subjects to see the investigator's notes.

You should allow forty-five minutes for them to complete all tasks.

2e Experimenters' script (first intervention)

i) Consent Form and Background Questionnaire

ii) Paper-folding Task

If less than the allotted three minutes, note the actual time to completion. They may not physically manipulate paper to solve the problems.

iii) Behavioural Tasks

- Ask the subject's permission to tape-record this section of the tasks
- If the subject declines, then thank them and end the session.
- If the subject agrees, then turn on the tape recorder.

Map drawing task protocol

- Offer the blank paper and pens/pencils of one colour.
- Direct the subject: "I would like you to draw me a map of the campus so that I can get from the <University Bookshop> to the <Main Computer Science Office>. Please include important path markers, the clues that a stranger would need to make the right decisions to get to the <Main Computer Science Office>. It's not important if you can't remember the names of streets and places. We don't expect an accurate drawing, just a sketch."
- Invite them to talk aloud as they work.
- Note the order in which they construct the map. (e.g., identifying both start and end point and then filling in the middle; or starting at start and drawing towards the end-point, adding features as they go).
- When the tell you they've finished, give the subject a different coloured pen and invite them to annotate their map with the "decision points" that someone would encounter if they used the map to walk the route.
- If they ask for a clarification, explain that "A decision point is an important path marker, the clue that a stranger would need to make the right decisions to get to the destination."
- For each decision point:
  Ask them to number the decision point.
  Ask: "How do I know when I've reached this decision point?"
  Ask: "What do I do at this decision point?"
- Make sure they number the points as they speak (so that the map can be correlated with the tape). They are free to append phrases or labels to their map if they wish to. If they wish to alter or correct the map, they may.
- Record their subject ID and the date on the back of their map. If there is more than one sheet, tape them together from the back *before you leave the room*.

Phone book task protocol

- Pass the subject the local phone book.

Search One:

- Direct the subject: "I would like you to look for <insert name> in the phone book" (Assure them that this is not a trick question, and that the name really does appear in it.) Provide the name – as it appears in the phone book – on a piece of paper.
- When they have found the name, ask them: "Could you please describe to me what you just did to find that entry?" If they find it difficult to articulate, you may use the following probes:
  1. "How did you open the book?"
  2. "How did you find the page?"

3. "How did you find the name on the page?

You may follow each of the above probes with a single additional request to add further detail, if you consider it to be necessary. You may not probe further than the single additional request. At that point, use the subject's response verbatim.

- Note the subject's ability to articulate (good/average/poor).
- Note whether their articulation correctly reflects their actions or is wrong. If wrong, note how it is wrong.
- If the subject has not already done so, ask them to close the book.

Search Two:

- Direct the subject: "Could you now look for <Ian McDonald>, and as you do this task, please describe exactly what you are doing and how you get to the entry". Again, provide the name – as it appears in the phone book – on a piece of paper.
- Note the subject's ability to articulate (good/average/poor).
- During this (second) search, you should use no probes, and make no requests for further detail. Use the subject's responses verbatim.
- Note whether their articulation correctly reflects their actions or is wrong. If wrong, note how it is wrong.

Alternatives:

- When they've finished, ask them once: "Can you describe any other ways in which you could have searched for that name, in this book? They need not be ways that you would use yourself."
- Do not probe for further detail, but you may ask "Are there any other ways?" until the subject is certain that they are finished.

Closing questions

"Thank you, that's really helpful. That's all the tasks, but it would help if we could have a few minutes of discussion" Ask the subject:

a) What do you think we were trying to find out?
b) How do you think the sketch-map task might relate to programming?
c) How do you think the phone book task might relate to programming?
d) What qualities or skills do you think are important to learn programming well, to "get it"?

Thank the subject, and turn off the tape recorder.
If the subject is interested, you may score the paper-folding test, and tell them their results.

2f Paper-Folding Test Scoring

If the subject takes less than the allotted three minutes, note the actual time to completion. For each subject, score the number of correct answers, the number of incorrect answers and the number of questions not attempted.

Part One

1. A
2. D
3. B
4. D
5. B
6. E
7. A
8. C
9. E
10. E

Part Two

11. C
12. B
13. A
14. E
15. B
16. A
17. E
18. D
19. D
20. C

2g Revised Study Process Questionnaire (R-SPQ-2F)

This questionnaire has a number of questions about your attitudes towards your studies and your usual way of studying programming.

There is no *right* way of studying. It depends on what suits your own style and the course you are studying. It is accordingly important that you answer each question as honestly as you can. If you think your answer to a question would depend on the subject being studied, please give the answer that would apply to your programming course.

Please fill in <the appropriate circle alongside the question number on the *General Purpose Survey/Answer Sheet*. The letters alongside each number stand for the following response>

A – this item is *never* or *only rarely* true of me
B – this item is sometimes true of me
C – this item is true of me about half the time
D – this item is frequently true of me
E – this item is always or almost always true of me

- Please choose the one most appropriate response to each question. <Fill the oval on the Answer Sheet> that best fits your immediate reaction.
- Do not spend a long time on each item: your first reaction is probably the best one.
- Please answer each item.
- Do not worry about projecting a good image. Your answers are confidential.
- Thank you for your co-operation.

1. I find that at times studying gives me a feeling of deep personal satisfaction.
2. I find that I have to do enough work on a topic so that I can form my own conclusions before I am satisfied.
3. My aim is to pass the course while doing as little work as possible.
4. I only study seriously what's given out in class or in the course outlines.
5. I feel that virtually any topic can be highly interesting once I get into it.
6. I find most new topics interesting and often spend extra time trying to obtain more information about them.
7. I do not find my course very interesting so I keep my work to the minimum.
8. I learn some thing by rote, going over and over them until I know them by heart even if I do not understand them.
9. I find that studying academic topics can at times be as exciting as a good novel or movie.
10. I test myself on important topics until I understand them completely.
11. I find I can get by in most assessments by memorising key sections rather than trying to understand them.
12. I generally restrict my study to what is specifically set as I think it is unnecessary to do anything extra.
13. I work hard at my studies because I find the material interesting.
14. I spend a lot of my free time finding out more about interesting topics which have been discussed in different classes.
15. I find it is not helpful to study topics in depth. If confuses and wastes time, when all you need is passing acquaintance with topics.
16. I believe that lecturers shouldn't expect students to spend significant amounts of time studying material everyone knows won't be examined.
17. I come to most classes with question in mind that I want answering.
18. I make a point of looking at most of the suggested readings that go with the lectures.
19. I see no point in learning material which is not likely to be in the examination.
20. I find the best way to pass examinations is to try to remember answers to likely questions.

3. Analysis Protocol

Paper-Folding

If the subject takes less than the allotted three minutes, note the actual time to completion. For each subject, note the number of *correct* responses, number of *wrong* responses and number of questions *not attempted* in each part of the test.

Map Task

For each institution:

- Scan a copy of a printed map of the area/campus you use. Identify the journey(s) you requested.

For each subject:

- Note the order in which they constructed their map:
  - 'route': identifying both start and end point and then filling in the middle
  - 'landmark': starting at start and drawing towards the end-point, adding features as they go
  - other.
- List the "decision points" they identified, as follows:
  - the decision point number;
  - the verbatim description;
  - categorise the decision point, using the "description taxonomy" below. (A decision point may fall into multiple categories);
  - if appropriate, note the associated action, using the verbatim description of the action, and categorise the action, using the "action taxonomy" below.
- The description taxonomy (categories for decision point descriptions):
  - *environmental*: this includes - visual landmarks such as archway, tree, pub (unnamed), topographical, such as "uphill" or "downhill" and other sensory descriptions
  - *functional*: calling landmarks by function, not by visual clues – "Go past the Human Nutrition Building" rather than "Leave the red brick building on your left"
  - *labelled*: this means the structure has is identified by a written sign, e.g. street name, pub name
  - *distance*: e.g., 'go three blocks'
  - *other*
- The action taxonomy (categories for decision point actions):
  - turn (this includes movement in all dimensions: left, right, up and down)
  - turn back (also, 'gone too far')
  - turn null (go straight ahead)
  - success (e.g., 'you're there')
  - other
- For example:
  1. "the Archway in the Students' Union Building"; (enviromental); "go through"; (turn null)
  2. "at Jones Street"; (labelled); "you've gone too far"; (turn back)
- Note if they ever provide elaboration of alternatives (e.g., "You could go this way, but it's more difficult." "Don't take Percy Street by mistake.")
- Note if they ever indicate the relative magnitude of the decisions and associated errors (e.g., "This would be a really bad one to get wrong.")

Phone Book

- Transcribe their articulation of search strategies.
- From the transcript, extract:
  - How do they open the book?

    - For each strategy employed, record: verbatim account. Categorise the strategy. (Strategy categories will be available on-line later in the year.)

    - How do they find the page?
    - For each strategy employed, record: verbatim account. Categorise the strategy.

    - How do they find the name?
    - For each strategy employed, record: verbatim account. Categorise the strategy.

- Transcribe their expression of alternatives.
    - For each strategy offered, record: verbatim account. Categorise the strategy.
    - Record the number of alternatives offered.

Closing questions

For each question, note interesting or unusual answers. If appropriate, note these verbatim.

Study Process Questionnaire

Score the Study Process Questionnaire according to the rubric at the end of the Biggs et al (2001).

4. Background

Design of study materials & pilot studies

The design of the tasks had a number of developmental inputs.

1. Disciplinary misconceptions

Scientists and engineers have developed "Concept Inventories" in many disciplinary areas, which identify common misconceptions that students have in technical subjects. We discussed their construction, use and utility with several engineering educators. We particularly discussed the possibility of constructing a "Programming Concept Inventory" to elicit common misconceptions in introductory programming. Subsequently, we discussed the notion of what might be a programming "misconception" with several experienced CS educators. During these discussions, Josh Tenenberg suggested some candidate disciplinary "pre-conceptions": " … students bring to programming their knowledge about interactions that they have with people and artifacts concerning (the control of) processes (how to fix the sink, how to install Windows XP, how to order things at a restaurant), transformations and manipulation of data and things (looking up names in phone books, sorting things, grouping things, arranging things, ...), and the linguistic description of these processes (e.g. recipes)."

2. Aptitude Tests

There is considerable commercial interest in aptitude testing for success in programming, and many companies offering materials. See, for example, (Daniel & Cox, 2003). There are also websites devoted to anecdotal reportage of specific approaches:

Microsoft Interview & other Riddles:
http://public.planetmirror.com/pub/riddles/microsoft.shtml
http://www.sellsbrothers.com/fun/msiview/default.aspx?content=question.htm
http://www.ocf.berkeley.edu/~wwu/riddles/intro.shtml

Wired article on puzzles etc in interviews:
http://www.wired.com/news/culture/0,1284,59366,00.html

Tech interviews for Dummies:
http://technicaljobsearch.com/interviews/technical-interview-tips.htm

However, it is not clear what (if any) their empirical foundation is. If extant, any such foundation would almost certainly be considered proprietary.

3. Attitude to Study

Ray Lister suggested (and work by Marian Petre, Matt Roddan and Rountree, Rountree & Robins supported the idea) that a primary indicator in regard to performance in programming courses was student attitude. It was clear that, whatever other intervention we might devise, this had to be accounted for. After some discussion, we settled on Biggs' Revised Study Process Inventory as our instrument.

4. Paper Folding study

In an early work examining the performance of professional programmers in a cross-cultural study, Marian Petre and her collaborators had used a spatial visualisation test based on suggestions in the literature that the test might relate to programming ability. That work found that all the professional programmers studied were good (some very good) at this test. We chose to use the task again to see if spatial visualisation ability correlated for entry-level programming.

5. Phone book

We returned to Josh Tenenberg's suggestion of "everyday" tasks. In particular, we had had experience of using the phone book task ourselves, in informal settings, and our experience was that non-programmers were poor at describing the search process. This suggested that the metacognitive ability to describe strategy might be relevant. We formalised the task and piloted it with three undergraduate students and two postgraduate subjects. The postgraduate verbalisations were thorough and exact. However, it was problematic for the investigator to note. We split the task into two stages, and introduced audio recording. This was piloted with a further four students.

6. Sketch map

Combining the ideas of spatial visualisation and articulation of strategy in an everyday task, we drew upon the literature and methodologies of city imaging and urban planning for the final task. In particular we drew upon Lynch's protocol, as detailed in appendix B of *The Image of the City* and Passini's notation from *Wayfinding in Architecture*. The task was piloted and refined simultaneously with the phone book task.

7. Open-ended questioning

Finally, we wanted this Kit to introduced a wide variety of tasks, approaches and analysis methods. To this end, we included a wholly qualitative, semi-structured interview section.

5. Literature

References (included in the Kit)

Literature that contributes to the question

Nathan Rountree, Janet Rountree and Anthony Robins *Predictors of Success and Failure in a CS1 Course* (2002) SIGCSE Bulletin vol. 34, no. 4.

Vikki Fix, Susan Wiedenbeck, Jean Scholtz (1993) *Mental representations of programs by novices and experts.* Proceedings of the SIGCHI conference on Human factors in computing systems.

John T. Bruer (1994) *Schools for Thought: A Science of Learning in the Classroom* MIT Press, Cambridge Massachusetts (chapter three)

Literature that contributes to the methodology

M. McCracken, V. Almstrum, D. Diaz, M. Guzdial, D. Hagan, Y.B.-D. Kolikant, C. Laxer, L. Thomas, I. Utting, and T. Wilusz. (2001) *A multinational, multi-institutional study of assessment of programming skills of first-year CS students.* Proceedings of ITiCSE.

John Biggs, David Kember and Doris Y. P.Leung. *The Revised two-factor Study Process Questionnaire: R-SPQ-2F* British Journal of Educational Psychology (2001) vol. 71 pp133-149

ETS Kit of Factor-Referenced Cognitive Tests, Educational Testing Service, Princeton, NJ (extract)

Background (optional reading)

… on potential factors

B. Cantwell Wilson & S. Shrock (2001) *Contributing to Success in an Introductory Computer Science Course: A Study of Twelve Factors* SIGCSE Symposium

Paul Curzon *Games & Puzzles* Interfaces 42

Paul Curzon (2001) *Computing without Computers* Unpublished Book

Graham Daniel & Kevin Cox (2003) *Computing Courses: Testing for Student Aptitude* Web Tools Newsletter http://webtools.cityu.edu.hk/news/newsletter/aptitude.htm

Ekstrom, R. B., French J. W. and Harman, H. H. *Cognitive Factors: Their Identification and Replication* (1976) Multivariate Behavioral Research Monographs No. 79-2

Mayer, R. E. (1989) *The psychology of how novices learn computer programming*. In E. Soloway & J. C. Spohrer (Eds.) *Studying the novice programmer* (pp 129-159) Hillsdale, NJ Lawrence Elbaum.

Matt Roddan (2002) *The Determinants of Student Failure and Attrition in First Year Computer Science* http://www.psy.gla.ac.uk/~steve/localed/roddenpsy.pdf

… on "misconceptions"

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Reem Nasr, Steven R. Hall and Peter Garick (2003) *Student Misconceptions in Signals and Systems and their Origins* 33rd ASEE/IEEE Frontiers in Education Conference. Session T2E-23. Available from: http://fie.engrng.pitt.edu/fie2003/

… on "deep learning"

Marton, F. & Saljo, R. (1976) *On qualitative differences in learning: Outcome and process*. British Journal of Educational Psychology, 46, 4-11.

Marton, F. & Saljo, R. (1997) *Approaches to learning*. In F. Marton, D. Hounsell & Entwistle, N. (Eds.) *The experience of learning. Implications for teaching and studying in higher education*. Edinburgh: Scottish Academic Press.

Richardson, J.T.E., Eysenck, M.W. & Warren Piper, D. (eds) (1987) *Student learning: Research into education and cognitive psychology*. Milton Keynes: Open University Press.

… on city imaging and urban planning

Arthur, P. and Passini, R. (1992) *Wayfinding: People, Signs and Architecture* McGraw-Hill Book Company: New York

Lynch, K. (1960) *The Image of the City* MIT Press: Massachusetts

Passini, R (1984) *Wayfinding in Architecture* Van Nostrand Reinhold Company: New York

Thiel, P (1970) *Notes on the Description, Scaling, Notation, and Scoring of Some Perceptual and Cognitive Attributes of the Physical Environment* in Proshansky, H. M., Ittelson, W. H. and Rivlin, L. G. (Eds.) *Environmental Psychology: Man and his Physical Setting*, Holt Rinehart and Winson Inc. : New York