Student perceptions of lecture approaches in first-year Engineering Physics

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Abstract: *A cohort of first-year Engineering Physics students was surveyed to explore student attitudes towards a variety of large-class lecture techniques, in the first four weeks of their tertiary education. The results are compared with previous studies of the preferred learning style of undergraduate engineering classes. Particular attention is given to student attitudes towards the use of a Personal Response System, as compared to more traditional lecture approaches.*

Introduction

Motivation

There are significant challenges and responsibilities associated with delivering to a group of students their first taste of tertiary education. In the present environment, the majority will be 'Generation Y', with significantly different attitudes and expectations from preceding generations. As described by Low, Wilson and Zadnik (2005), these students are 'digital natives', never having experienced a world without the internet, and accustomed to a random or parallel information access model (Google, Wikipedia) as opposed to the linear models of the past (reference books, libraries). They are the most connected and interdependent people in the history of the world; and when they want something, they typically want it – and expect it – 'now', not later. Naturally, these attitudes and expectations run somewhat counter to the university environment, where research takes years; careful, precise measurements are desired; and rigorous theory underpins the development of natural models.

This study originated in an informal discussion amongst teaching staff, regarding what students 'wanted' from their coursework. With some admitted hyperbole in the framing of the following rhetoric: do students come to university hoping to be freed from the structure of primary/secondary school? Or do they just want to be told exactly what to do? Do they change attitude from the former to the latter state as they progress through their studies? And if they do, whose 'fault' is that?

The transition from secondary to tertiary education provides an opportunity to begin the active conversion of students from what Baxter Magolda (1992), integrating a number of models of intellectual development, calls 'absolute knowing' (where the teacher is an authority, imparts the Truth, and students do not question it), to a view of the world where one appreciates that most knowledge is uncertain, most truths are contextual, and that it is an individual's responsibility to make judgements in the face of ambiguity ('independent' or 'contextual' knowing). After all, if this process is not begun at the point of educational transition, there is the danger of missing the opportunity altogether if students relax into an intellectually less-challenging mode of learning.

The aims here are: to review previous studies of learning styles, particularly the similarities and differences between science and engineering students; to provide examples of how varied teaching styles can both support students, and draw them out of their comfort zone; and to explore the attitudes of one cohort of first-year engineering students towards a variety of lecture techniques, in the first few weeks of their tertiary careers, before any 'intellectual conversion' has taken place. Particular attention is given to student attitudes towards interactive peer-instruction, as compared with more traditional large-class lecture approaches.

Learning Styles and Teaching Styles

While the idea that students can be broadly grouped into categories which reflect their natural and/or preferred ways of obtaining and processing information is not universally accepted on theoretical grounds, the concept of 'learning styles' allows for a useful and practical categorisation. For a general discussion and comparison of learning style models, see (for example) Lawrence (1982) and De Bello (1990). Teaching style models classify instruction on the basis of how they address learning style components. For example, students favouring visual representations respond well to pictures and charts rather than verbal (written or spoken) discourse; some students respond better to an instructor presenting concepts and theories rather than facts or recipes. The natural human learning process, as seen in the behaviour of children, is inductive: try something, observe the results, and draw inferences about life. Given that an instructor already understands the material, however, teaching often tends more towards a deductive approach: starting from the governing principles, and working towards applications (Felder & Silverman, 1988).

A number of studies, incorporating a variety of models, have been made of the distribution of engineering students' learning styles; a meta-study by Felder and Brent (2005) summarises the common points and differences of the main models. Three models seen as particularly relevant to students in science and engineering courses (Larkin & Budny, 2005) are worth noting here. It should be appreciated, however, that learning style models are simplistic, and aim to paint a broad canvas with just a few shades: individual students are unique.

Psychological Types (Jung 1971, Myers & McCaulley 1985)

Psychological types, as introduced by Jung (1971), have been codified into the well-known Myers-Briggs Type Indicators (MBTI): four index-pairs, relating to an individual's tendency towards each of [**I**ntroversion/**E**xtroversion], [**S**ensing/i**N**tuition], [**T**hinking/**F**eeling], and [**J**udging/**P**erceiving] (Myers and McCaulley 1985). Those students with a bias towards the '**S**ensor' type focus on reality, observables and the practical; they prefer standard methods which can be repeated, and are patient with detail. 'I**N**tuitors', on the other hand, are more appreciative of concepts and theories, and tend to score higher on traditional academic assessment tasks; they can be bored by detail, but enjoy innovation. From a science/engineering point of view, it is worth noting that I**N**tuitors are generally more comfortable with symbols, and are generally quicker at deriving meaning from words or equations (Felder and Silverman 1988).

From an MBTI perspective, first year engineering and physics classes are both dominated by **I, T, J** types, with a relatively weak bias in the second index towards **S** and **N** respectively (O'Brien, Bernold and Akroyd 1998; Rosati 1998); broadly consistent, perhaps, with the notion that undergraduate engineers are more practical-oriented than their physics/science peers. This can be compared with traditional teaching styles in those disciplines of **I** (lectures, tests), **N** (fundamentals, concepts, symbols), **T** (objective analysis) and **J** (covering a syllabus, rather exploration of a field).

Learning Style Inventory (LSI; Kolb, 1984)

The LSI (depicted in Figure 1) considers two parameters: a student's preference to perceive information via a 'feeling' (experience) or 'thinking' (conceptualisation) approach (which O'Brien, Bernold and Akroyd (1998) and Rosati (1998) have shown to correlate well with the **S**ensing/I**N**tuition index of the MBTI); and a student's preference to process information via a 'doing' (experimentation) or a 'watching' (observation) approach. The four quadrants that result from these two axes then characterise the four learning types of Kolb's model: the Diverger (Type I) is generally motivated by relating course material to interests, and learns by discussion/sharing; the Assimilator (Type II) appreciates structure, organisation and rules, and likes to learn from an 'expert' presenting 'truth' (students who display traditional 'academic excellence', and do well at school, are usually in this category); the Converger (Type III) likes to test and experiment, enjoys laboratory work, and particularly benefits from guidance and feedback on their explorations; and the

Accommodator (Type IV), who enjoys adapting knowledge to new situations, open-ended problem-solving, and self-discovery, with the instructor acting as an evaluator.

Kolb's LSI model categorises most engineering students as Type II/III learners, while traditional undergraduate science/engineering teaching is of Type II (Felder & Brent, 2005).

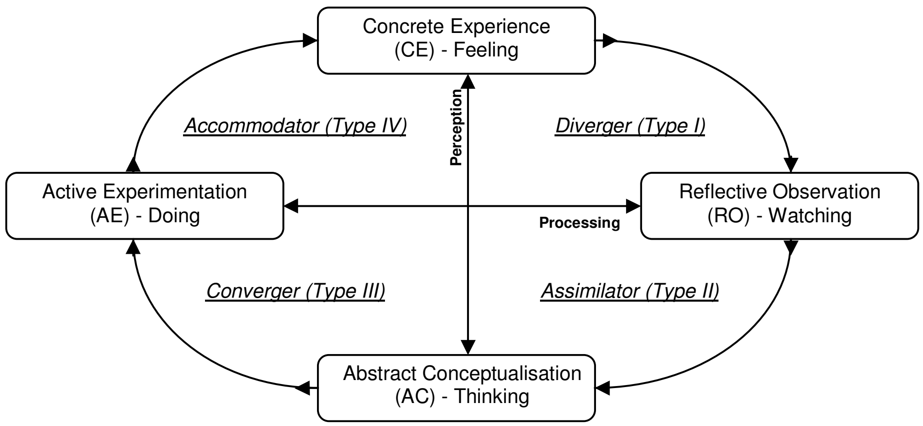

Figure 1: Kolb's learning style model (after Hein and Budny 1999)

Index of Learning Styles (ILS; Felder & Silverman, 1988)
The ILS features five parameter pairs: the first two (active/reflective and sensing/intuitive) match the Kolb model (the 'processing' and 'perception' axes in Figure 1 respectively); the other three are visual/verbal (does a student prefer illustrative pictures or descriptive words?), sequential/global (does the student prefer linear/convergent thinking and analysis, or intuitive leaps and synthesis?), and inductive/deductive (does the student prefer to observe and draw inferences, or to make deductions from governing principles?). The inductive/deductive pair had been removed from the model by the time of Felder and Brent's (2005) meta-study.

Under this model, most science/engineering students are active/sensors/visual/sequential learners (albeit with significant 'intuitive' and 'global' minorities), while traditional science and engineering teaching tends to be reflective/intuitive/verbal/sequential (Felder & Silverman, 1988; Rosati, 1998).

'Match' versus 'Mismatch'? Or 'Cater' versus 'Challenge'?
The consistent pattern that emerges is that engineering students have more of a bias towards sensor-type learning than their physics/science peers; while instructors – either by nature, or due to external pressures such as time and workload – tend to present via an intuitor style (Rosati, Dean & Rodman, 1988). However, regardless of the majority in a large sample, any class will comprise a (potentially wide) range of learning styles or preferences, many of whom may be largely at odds with the majority! It is arguably beneficial for students to have skills associated with *all* learning styles, in order for them to function effectively in their future careers: if the instructional technique(s) used matched all students perfectly, there would be little or no incentive for students to develop other – perhaps critical – skills in their less-preferred styles. Balance in teaching techniques here is the key: individualised teaching is impractical, while a single model is likely to be ineffective at reaching a significant proportion of a class. An example of balance is to teach 'around the circle' in Figure 1, which in many ways models the natural learning process. Starting from the top of the diagram (CE), for example: gather first impressions based on previous experience; observe how things work; hypothesise and/or model; test; and repeat the process, now with some new impressions about nature.

Numerous examples of how to appeal to a variety of learning styles are given by (e.g.) Felder, Woods, Stice and Rugarcia (2000), and Hein and Budny (1999). A summary, based on the discussion above, is presented in Table 1.

Selected Learner Types	Sympathetic Teaching Activities
Sensor *(MTBI S-type, Kolb CE/Feeling)*	- Examples with numbers rather than symbols; standard methods; relate to reality;
Intuitor *(MTBI N-type, Kolb AC/Thinking)*	- Symbols, concepts, theories, models.
Active *(Kolb AE/Doing)*	- Group activities, laboratories, discussion;
Reflective *(Kolb RO/Watching)*	- Reading, listening, reviewing.
Visual	- Sketches, graphs, flow-charts;
Verbal	- Explanations, derivations.
Diverger *(Kolb Type I)*	- Appreciating the big picture;
Assimilator *(Kolb Type II)*	- Organised presentation of material, examples;
Converger *(Kolb Type III)*	- Learn by doing, focussed, 'one correct answer';
Accommodator *(Kolb Type IV)*	- Small peer-group work, discussion, self-discovery.

Table 1: Selected learning styles and related teaching approaches.

Investigation of Student Perceptions

Cohort and Context

The cohort surveyed consisted of 106 first-semester first-year undergraduate students (of which 90 responded) studying Engineering (Civil, Mechanical, and Aeronautical) and Technology (Aeronautical Engineering, and Aviation) degrees, after the first four weeks (12 lectures) of an Engineering Physics service course ZPEM1503 at the University of New South Wales at the Australian Defence Force Academy (UNSW@ADFA). The material presented – 'General Physics and Mechanics' (GPM) – covered a standard first-year mix of kinematics, dynamics, work, energy and momentum. Undergraduate students at UNSW@ADFA live in shared accommodation on campus, play team sports and engage in adventure training activities together, are subject to regular academic and military performance reviews, and know that they will have ongoing links with each other throughout their future careers as officers in the Australian Defence Force. They therefore display a homogeneity which may be distinct from the undergraduate body at other institutions.

Lecture Techniques

GPM utilised a number of teaching techniques in the lecture-room environment (see Table 2), in order to provide diversity in the student learning experience, and give students something different to look forward to in every class. The interactive class questions (**Q**) took the form of 'peer instruction' (Mazur 1997), conducted via a Personal Response System (PRS; *InterWrite Learning™ Cricket* handsets) provided to the class. Activities outside the large-class lectures, such as the weekly small-class tutorials (conceptual discussion and problem solving) and the laboratory program (which did not commence until after the GPM section had concluded), were excluded from this study.

Survey Instrument

At the end of the final GPM lecture, students were anonymously surveyed on their attitudes towards the various teaching approaches employed. The main item on the survey asked students to rate each of the five techniques independently on a scale from 1 ('the best') to 5 ('useless'), with regards to how each one 'helped students learn, and engage with the material'. Other items were specifically concerned with the implementation and use of the PRS trial: four Likert-scale questions, exploring a student's personal frequency of participation, attitude towards anonymity, impact on learning, and preference for future use; and two write-in opportunities for students to state one good thing and one bad thing about the PRS approach.

Activity	Examples	More Appeal	Less Appeal
T – presentation of textbook material	Derivations, background theory	Intuitor, Reflective, Assimilator	Sensor, Active, Accommodator
B – problem-solving by lecturer on whiteboard	Worked examples, application of techniques	Sensor, Converger, Assimilator	Active, Diverger, Accommodator
D – demonstrations (some with participation)	Projectile motion, collisions, poppers, astro-blaster.	Sensor	Intuitor
Q – interactive class questions	Pair-wise discussion of conceptual/graphical/calculation multiple-choice questions	Active, Converger, Accommodator	Reflective, Diverger,
C – supplementary discourse ('chats') by the lecturer	'What is mass, really?', 'Forward passes: are referees blind?', 'Red-outs and Black-outs: pilots and acceleration'	Diverger, Accommodator	Converger, Assimilator

Table 2: Teaching activities used in GPM large-class lectures, and their relationship with preferred learning styles.

Results and Analysis

Given that the five techniques were rated independently (i.e. students could use the same rating for multiple techniques), analysis of relative preferences were carried out via a sequence of point-to-point differences via t-tests. In this way, each technique was compared with every other technique, exploring for consistent biases in student attitudes; the results are displayed in Table 3. Noting that a low numerical rating indicated a positive preference, negative (*positive*) t-test values indicate that the first (*second*) of each technique-pair is the preferred instructional method; t-test values of absolute magnitude greater than 1.67 (1.29) are significant at the 5% (10%) level (N = 90).

	T-B	T-D	T-Q	T-C	B-D	B-Q	B-C	D-Q	D-C	Q-C
Average	0.83	0.77	0.64	0.27	-0.07	-0.19	-0.57	-0.12	-0.50	-0.38
Sigma	1.59	1.72	1.70	1.71	1.61	1.56	1.79	1.23	1.47	1.49
t-Test	4.98	4.24	3.60	1.48	-0.39	-1.15	-3.00	-0.95	-3.23	-2.41

Table 3: Point-to-point difference analysis between five lecture techniques (presentation of material from the **T**extbook, lecturer problem-solving on the **B**oard, **D**emonstrations, **Q**uestions done with the class via PRS, and supplemental **C**hat)

Students rated lecturer-driven problem-solving, demonstrations, and PRS questions about equally popular at the top of the list (with a low significance preference to the written order), while presentation of material was a significant lowest preference. This is consistent with the Sensor traits (practicality, reality, standard methods) previously discussed as being predominant in undergraduate engineering cohorts. Furthermore, an examination of the logged PRS records indicates a greater participation rate and performance in graphical interpretation questions than was seen with numerical/symbolic questions, consistent with a visual (as opposed to verbal) preference. Supplementary discourse displayed a wide spread of results – reflecting, perhaps, how much any particular chat interested or inspired different segments of the cohort.

In an effort to determine attitudes towards the PRS approach in particular, the students' written comments were explored via a categorical analysis. Out of 89 written-in 'one good thing' comments about the PRS trial, almost half of the cohort (39/90) stated that 'seeing where they stood in relation to the rest of the class' was the best thing, 15 identified 'the active nature of the activity', and 11 nominated 'providing guidance to the lecturer'; only nine responses identified 'checking understanding of the material'. Six or fewer students identified each of 'immediate feedback' (which could be linked with the first category noted above) and ‘simulating test conditions’ as their single positive

In comparison, there were only 50 written-in ‘one bad thing’ comments, with 22 of them nominating ‘the time investment’ as being the biggest weakness of the PRS: these students expressed a concern that the PRS approach ‘took time away from doing more worked examples’ (linked, perhaps, with the popularity of lecturer-driven problem solving identified earlier). The only other significant downside identified with the clicker approach was ‘the time pressure’ to complete questions: 11 respondents expressed a preference to ponder, or ‘nut out’, questions. Other responses, each identified by five or fewer students, included comments along the lines of the PRS being a ‘distraction’, issues with using technology, and a feeling that the PRS activities were not taken seriously by some in the class.

While drawing conclusions from a linked comparison of the categorised written comments with the numerical lecture-technique preferences is difficult due to the small numbers involved in some cases, some aspects are significant enough to mention here. Those students who identified one good thing about the PRS to be the active nature of that activity, were significantly ($p > 0.95$) more likely to rate demonstrations (understandably) and presentation of material from the text (surprisingly?!) as good/preferred teaching techniques. Those students concerned about the time investment of the PRS technique were significantly ($p > 0.90$) less enthusiastic about using the PRS in the future, preferring (understandably) more “board work”, but were significantly ($p > 0.95$) more interested in the supplemental discourses.

Discussion

While there are potential complications in interpretation due to convolving student learning styles with the relative ability of the lecturer to deliver each of the variety of techniques, the cohort surveyed displays attitudes towards learning which are consistent with a variety of learning style models. It is also apparent that significant minorities with a spread of learning-style preferences are present within the cohort. This is perhaps unsurprising, given the differences one may expect between Sensor-biased ‘hands-on’ engineers (civil, mechanical), while aeronautical engineers may have a bias towards Intuition (O’Brien, Bernold & Akroyd, 1998). This emphasises the need for a variety of teaching styles to be employed, in order to both engage different styles of learner by playing to their strengths, and to challenge students to see the world from a different viewpoint. That new outlook may be one with which a student is initially less comfortable, but the skills and approaches required to understand it are likely to be required at some stage in their future careers.

Further Work

In 2010, first-year engineering and science students at UNSW@ADFA will be combined into a single physics course. Repeating this study, with the inclusion of degree (and possibly gender) identifiers, will enable a more comprehensive comparison of learning styles with preferred teaching styles. The class balance in 2010 is likely to be more evenly spread between Intuitor-types (the physicists and design engineers) and Sensor-types (the hands-on engineers). In addition, while assessment has not been discussed here, it may prove instructive to compare students’ preferred learning styles with their performance on different types of assessment. For example, one might expect Intuitors to perform better on conceptual questions or derivations (where Sensors may struggle, even if only by taking more time), while Sensors may find numerical problems better suited to their nature. The combined class of 2010 will make direct comparisons possible in this regard.

Acknowledgements

The PRS was purchased with the assistance of a UNSW@ADFA Learning and Teaching Performance grant (UNSW@ADFA Human Research Ethics Advisory Panel approval A-09-03), awarded jointly to the author and Dr James Connor (JC) of the School of Business, UNSW@ADFA. JC also provided feedback on the design of the survey instrument described herein, and guided that document through Ethics approval, for which the author is truly thankful and appreciative.

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