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Students' responses to different first year science learning environments

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Abstract: *One way of evaluating a learning situation is to investigate the psycho-social learning environment, which provides an indication of how students perceive the teaching, their learning and their relationships with others in the class. This research study compares two first year university science learning environments – a traditional lecture/tutorial-based mode and a workshop, studio mode. Students were surveyed using the University Social Constructivist Learning Environment Survey and results on two common assessment tasks were also collected. The data show that the studio learning environment was rated more highly on five of the six scales, Relevance, Negotiation, Leadership, Empathy and Support, indicating a higher degree of learner-centredness as perceived by students. Multidimensional scaling produced holistic spatial representations of the two learning environments revealing a closer match between the actual and preferred learning environments in the studio classes compared with the traditional classes. Comparisons between students' assessment results and their preferred learning environment point to possible attitude differences between students in the different groups as well as between students with differing results in each group. This study raises questions about course design in science subjects.*

Keywords: *Learning environment; studio physics; learner-centredness; teaching and learning science.*

Introduction

Many tertiary institutions in Australia are experiencing financial constraints forcing some to seek more cost-effective ways of teaching a growing number of students. Instructing large numbers of students in lectures will flourish in such economic conditions, especially where tutorials can be conducted by lower paid tutors. An alternative to the lecture/tutorial combination is a computer-supported studio/workshop form of instruction, which allows for some increases in efficiency through reduced class contact time (Wilson, 1994). This study compares student perceptions of these different learning environments and makes inferences about the learner-centredness of the two instructional modes.

Learner-centred practice in higher education

There is growing support in higher education for a change in focus from teaching to student learning – from teacher-centredness to learner-centredness. This shift has been supported and endorsed by educational theorists, professional education bodies and higher education institutions (Huba & Freed, 2000). To illustrate this point, Curtin University of Technology's Teaching and Learning Strategic Plan 2001-2005, (Curtin, 2001) identifies the "Establishment of high quality educational programs in a flexible, learner-centred environment," as one of its primary teaching and learning outcomes.

Recent education research, much of it based on constructivist epistemology, supports teaching methods other than passive lecture-discussion formats where teachers do most of the talking and students listen (Hake, 1998; Hendry, 1996; Huba & Freed, 2000). The incorporation of learner-centred practices in line with a constructivist epistemology has already been central to changing practices in a number of tertiary science classes (Taylor, Gilmer & Tobin, 2002). From a constructivist view, meaningful learning is a cognitive process in which individuals make sense of the world in relation to the knowledge which they have already constructed. This sense-making process is learner-centred in that it involves students in active negotiation and the development of new knowledge through consensus-building processes. It should be possible, therefore, to explore elements of learner-centredness in classrooms by seeking evidence of constructivist practice.

Learning environment research

Learning environment research developed, inpart, from Moos' work on evaluating educational environments (Moos, 1979). In classrooms, students' motivation and learning behaviours can be affected as much by the psychosocial environment as they are by teaching methods or the subject matter. A learning environment instrument consists of a number of scales representing different dimensions of the learning environment, such as personal relationships, teacher support, interactions with peers and so on. Students' positive perceptions of their learning environment have been linked with enhanced cognitive outcomes (Wubbels, Brekelmans & Hooymayers, 1991), positive attitudes to their class (Henderson & Fisher, 1998; Nair & Fisher, 1999) and enhanced student satisfaction (Fraser & Treagust, 1986), all of which may be related. As Henderson and Fisher (1998) point out, a positive attitude is more likely to sustain student interest and thus promote learning.

There are also "actual" and "preferred" forms of many surveys; the "actual" form asks students to describe the environment they are experiencing and the "preferred" form asks students what they regard as their ideal environment. A student's ideal environment might be shaped by his/her goals or expectations and hence might be different from what they are experiencing. The difference between actual and preferred scores can give a measure of students' satisfaction/dissatisfaction with their experienced learning environment (Fraser, 1998).

University Social Constructivist Learning Environment Survey (USCLES)

Taylor, Fisher and Fraser (1996) developed the USCLES to enable an assessment of the extent to which teachers are adopting a constructivist approach in tertiary classrooms. They based the theoretical design of this instrument on a social constructivist model of cognition which describes a supportive classroom environment engaging students in activities promoting opportunity for:

- making the subject "personally relevant";
- demonstration of care and concern for all students;
- students to comfortably admit the uncertainty of their knowledge; and
- students to consider all views and the possibility of more than one "correct" answer.

The first three USCLES scales, *Relevance*, *Reflective Thinking* and *Negotiation*, focus on student-related characteristics of learner-centredness; opportunities for students to engage in communicative activity such as discussion of difficult ideas, scientific reasoning, solutions to problems and reflective thinking about their role in learning. Such processes lead to deeper conceptual understanding within the discipline (Taylor et al., 1996). See Table 1. Scales 4-6, *Leadership*, *Empathy* and *Support*, are about the types of interpersonal qualities that a university teacher needs to help students change their approaches to learning into ones more in line with a constructivist epistemology. In effect, they assess the degree to which the teacher is adopting a learner-centred approach in his/her relationship with students.

Table 1: USCLES scales and sample items from *actual* and *preferred* forms

Scale	Sample item *Actual* Form	Sample item *Preferred* Form
Relevance	In this class, my learning focuses on issues that interest me.	In this class, I would prefer that my learning focuses on issues that interest me.
Reflective Thinking	In this class, I learn how to become a better learner.	In this class, I would prefer that I learn how to become a better learner.
Negotiation	In this class, other students ask me to explain my ideas.	In this class, I would prefer that other students ask me to explain my ideas.
Leadership	In this class, the lecturer talks enthusiastically about his/her subject.	In this class, I would prefer that the lecturer talks enthusiastically about his/her subject.
Empathy	In this class, the lecturer realises when students don't understand.	In this class, I would prefer that the lecturer realises when students don't understand.
Support	In this class, the lecturer is someone students can depend on.	In this class, I would prefer that the lecturer is someone students can depend on.

(Taylor, Fraser & Fisher, 1997)

The five-point Likert scale ranges through Almost Always (=5), Often (=4), Sometimes (=3), Seldom (=2) to Almost Never (=1). Hence the numerical responses indicate students' perceptions about the degree or frequency that the stated practices occur or are experienced (the "actual" form) and the degree or frequency that they would prefer the practices to occur or that they would be experienced (the "preferred" form).

Learning physics

Most physics students come to university expecting structured lessons, an emphasis on solving numerical problems and to be provided with relevant notes or summaries (Donald, 1994). They tend to want lecturers to give them simplified versions of physics concepts and explanations that they can learn, and problems that do not require "complicated" mathematics (Yeo, 2002). Arguably, these are amply provided to students in a traditional lecture/tutorial mode of instruction. Studio students, on the other hand, may need to adapt their accustomed learning behaviours to suit the activities in the Studio unit. One might therefore expect students to respond less favourably to a learning environment that does not meet their expectations unless their views of learning have been influenced by new experiences. Another factor that might affect students' responses to the learning environment is their success. Students who have performed well (achieved higher marks) might be expected to respond more favourably to their learning situation than those who have performed poorly (Wubbels et al., 1991).

Multidimensional scaling

The process of multidimensional scaling uses measures of various parameters (or "objects") of the situation under study and locates them in two or three-dimensional space in positions that reflect their similarity or difference. Objects that are similar in some way are located close together and those that are different are located further apart. Distance represents degree of dissimilarity. Similarity data can be any measure of similarity between two objects of interest, including correlation coefficients (Coxon, 1982; Kruskal & Wish, 1978). Multidimensional scaling has been proposed as a way to compare different learning environments or to explore changes in environments following an intervention (Salomon, 1996).

Research design and methodology

This study compares the perceptions of first year physics students who are engaged in different instructional modes about their experienced and preferred learning environments, and uses multidimensional scaling to compare them in an holistic way. The two instructional modes are:

1. A traditional lecturing style of instruction with two hours of lectures and a one-hour tutorial per week. Students are provided with lecture summaries. Opportunities for interaction and discussion exist in tutorials. There are approximately 130 students in the unit and about 25 per tutorial. This group will be referred to as the Lecture-Tutorial Instruction Group (LTI).
2. A computer-supported studio style of instruction with one two-hour workshop per week. The pedagogical approach uses "interactive engagement" strategies (Hake, 1998) with ample opportunity for student discussion and elaboration of ideas. Two instructors, one of whom one is nominally a tutor, are present in each class. There are no formal lectures and no lecture notes are provided. There are approximately 50 students in the unit, with about 25 per class. This group will be referred to as the Studio Instruction Group (SI).

Research questions

The following research questions are addressed in this paper.

- How do first year physics students in the different instructional modes perceive their respective learning environments?
- To what extent are they satisfied with their respective learning environments?
- Are students' perceptions of their learning environment related to measures of their academic success?

Method

A subset of students from each class type, matched on prior physics knowledge and ability, gender and first language, was selected for comparison. The matching data for prior physics knowledge and ability were students' scores on the university entrance physics exam and their Tertiary Entrance Rank. The LTI matched group consisted of 70 students (mostly engineering majors) and the SI matched group consisted of 45 students (roughly one third each of physics, geophysics and multidisciplinary science majors). The USCLES combined Actual and Preferred form was administered to all students who attended classes in week 3 of Semester 2. Measures of students' success were their results on the Semester 1 examination (EXAM), a multiple choice instrument consisting mostly of calculation-type and conceptual questions, and Quantum Mechanics test (QM TEST), a multiple choice test of highly abstract concepts.

Results and interpretation

Students' actual (experienced) learning environment

The data indicate that SI students perceive their learning environment as consisting of more frequent student-centred, constructivist practices than do LTI students on all scales but *Reflective Thinking*, where both groups perceive the same frequency of activity. See Table 2. SI students' perceptions of the frequency of learner-centred activity on all scales range from 3.28 to 4.37 (average 3.89). They report the lowest frequency of activity for *Reflective Thinking*, which encompasses different aspects of metacognition – student awareness of their own learning behaviours. This is an important result considering that the Studio course employs several strategies to guide students' reflective practices.

Table 2: SI and LTI students' responses to the USCLES *actual* form – means, standard deviations and differences

	SI (N=37)		LTI (N=60)		
USCLES scale	**Mean**	**SD**	**Mean**	**SD**	**Diff (SI-LTI)**
Relevance	3.66	0.49	2.81	0.61	0.85***
Reflective Thinking	3.28	0.46	3.18	0.66	0.10
Negotiation	3.70	0.78	2.95	0.74	0.75***
Leadership	4.08	0.56	3.18	0.80	0.88***
Empathy	4.37	0.57	3.45	0.64	0.92***
Support	4.22	0.64	3.08	0.68	1.13***

*** $p<0.001$

LTI students' estimates of the frequency of learner-centred, constructivist activity on all scales range from 2.81 to 3.45 (average 3.10). Thus the average response of these students to the frequency of the listed activities is "sometimes", meaning LTI students do not consider that learner-centred practices are non-existent or even particularly low in frequency. Since they were given the survey during tutorials, their responses may reflect tutorial experiences where there is a greater likelihood of discussion and personal contact between teacher and students than in lectures.

Students' preferred learning environment

Both groups of students have similar "preferred" learning environments. See Table 3. They are similar in how much *Reflective Thinking* and *Leadership* that they want, but rate *Reflective Thinking* and *Negotiation* lower among their preferences, suggesting that both groups do not want (or expect) to take much responsibility for directing or controlling their own learning.

Table 3: SI and LTI students' responses to the USCLES *preferred* form – means, standard deviations and differences

	SI (N=37)		LTI (N=60)		
USCLES scale	**Mean**	**SD**	**Mean**	**SD**	**Diff (SI-LTI)**
Relevance	4.33	0.43	4.02	0.47	0.31**
Reflective Thinking	3.96	0.55	3.76	0.65	0.20
Negotiation	3.94	0.70	3.61	0.68	0.34*
Leadership	4.57	0.36	4.46	0.48	0.11
Empathy	4.73	0.35	4.23	0.47	0.50***
Support	4.59	0.43	4.24	0.57	0.36**

*** $p<0.000$ ** $p<0.01$ * $p<0.05$

Differences between actual and preferred learning environments

The magnitude of the difference between students' perceptions of their preferred learning environment and their actual learning environment is interpreted as a measure of students' dissatisfaction with the actual learning environment. The average difference between actual and preferred scales is 0.46 (about half a scale unit) for SI students and 0.95 (about a whole scale unit) for LTI students. See Figure 1. The greater the difference, the more dissatisfied students are with their learning environment (Fraser, 1998). In this instance, it can be inferred that LTI students are more dissatisfied with these aspects of their learning environment than are SI students.

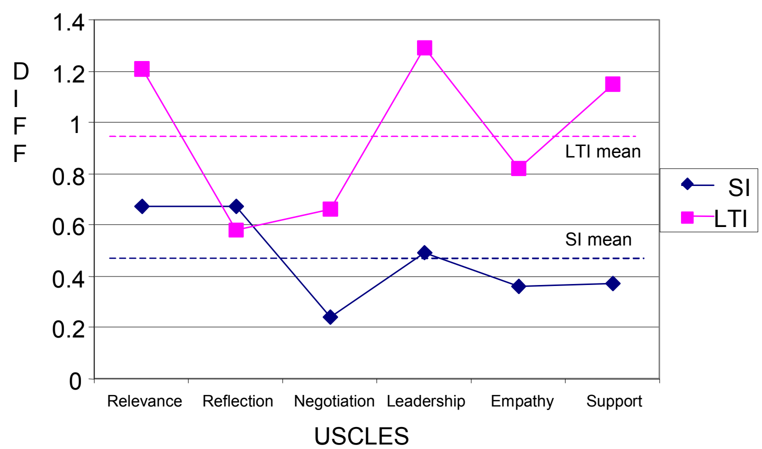

Figure 1: Differences between SI students' and LTI students' actual and preferred learning environment scores. The greater the difference, the more dissatisfied the students are with their actual learning environment.

Although the evidence suggests that students in the Studio learning environment are more satisfied with their experiences, is this consistent among all students? That is, do all students want an equal increase in learner-centred experiences or do some want much more and others want less? Is there any difference between the preferences of SI students and LTI students? One way to answer this is to examine the correlations among students' actual and preferred learning environments. While correlation data are easily produced, interpreting or finding patterns in the data is more complex. This is where multidimensional scaling (MDS) is useful. Correlations among SI and LTI students' actual and preferred learning environment scales were subjected to metric multidimensional scaling. Two-dimensional solutions using squared Euclidean distances produced a reasonable fit and interpretable solution in each case:

SI matrix: stress = 0.17, RSQ = 0.93 LTI matrix: stress = 0.13, RSQ = 0.94

Two ways of interpreting these representations are to compare (1) distances between points of interest and (2) areas or groupings of points of interest.

Distances between points

In the SI map (Figure 2), the locations of the actual learning environment points are relatively close to the location of the preferred learning environment points, whereas in the LTI map (Figure 3) the locations of the actual learning environment points are, on average, further away from the preferred learning environment points. Inferences based on these spatial maps are that there is more uniformity in SI students' opinions i.e. there are fewer students who, if perceiving there to be a low frequency of an activity, want there to be a much higher frequency and vice versa. In general, these students want the same type of learning environment, only more of it. In contrast, in the LTI map, the preferred learning environment appears to bear less of a relationship to the actual learning environment on all of the scales. This suggests that there is less uniformity of opinion, with students' preferred learning environment being comparatively less related to what they are experiencing.

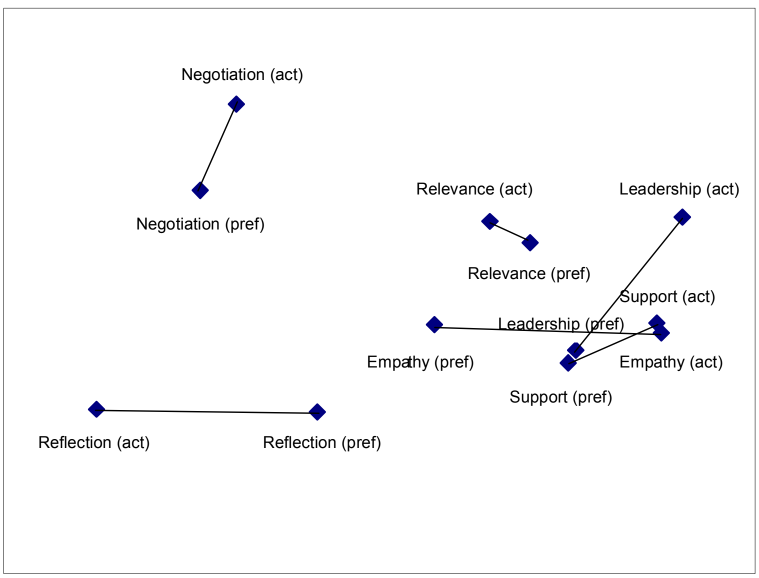

Figure 2: MDS representation: Shows relative distances between SI students' actual and preferred learning environments.

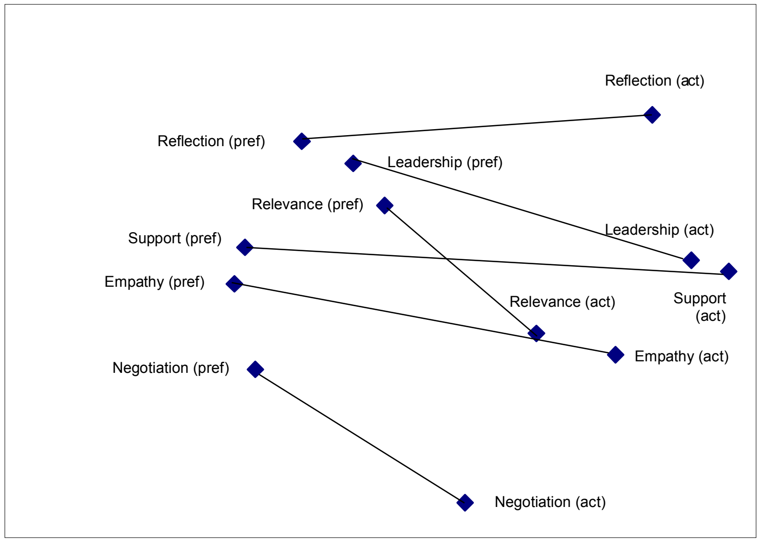

Figure 3: MDS representation: Shows relative distances between LTI students' actual and preferred learning environments.

Groupings of points

An interesting feature of the LTI maps is the apparent dichotomy between actual and preferred learning environments compared with the SI maps in which there is more integration between actual and preferred data points. See Figures 4 and 5. In part, this is a consequence of the lower correlations between actual and preferred data sets, but also of the relatively higher correlations among the preferred learning environment scales compared with the actual learning environment scales. This suggests that in comparison with SI students, LTI students who want more frequent learner-centred activity on one scale tend to want a similar increase on the other scales and vice versa. A possible explanation is that LTI students are basing their preferences on simply wanting "more of everything" rather than on reflection about their actual experiences.

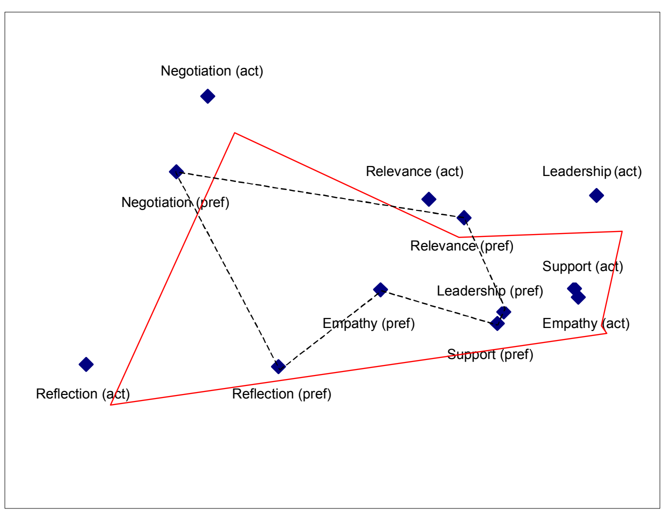

Figure 4: MDS representation: Shows integration of SI students' actual and preferred learning environment groups.

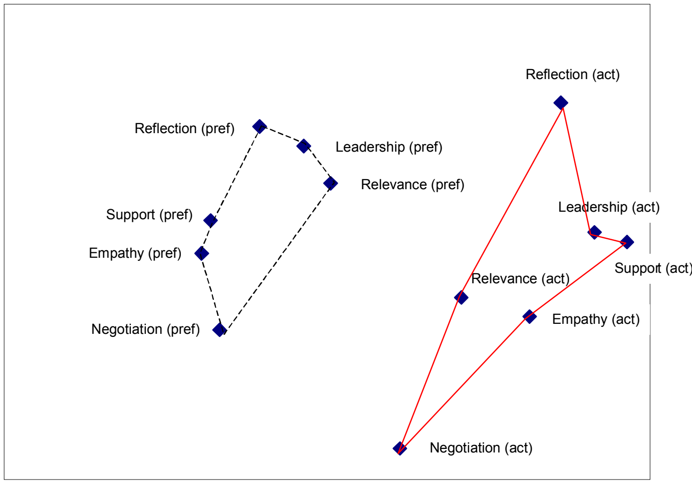

Figure 5: MDS representation: Shows grouping and separation of LTI students' actual and preferred learning environment groups.

Some tentative assertions drawn from this analysis are that:

- SI students are familiar with, and have a richer understanding of, learner-centred experiences and therefore offer more consistent opinions than do LTI students.
- LTI students' preferred learning environment depends less on their understanding of the nature of a learner-centred learning environment and more on other attitudes or characteristics of the students. Some students consistently want a much greater amount of each type of activity, regardless of their perceptions of what exists. We suggest that this indicates a poorer of understanding of what learner-centred engagement means, a plausible conclusion for classes that experience little real active learner involvement.

Thus, we have suggested that an analysis of students' responses to their experienced and preferred learning environment has revealed not only differences among the perceptions of SI and LTI students, but also differences between SI and LTI students' understanding of a learner-centred learning environment.

Students' success and perceptions of the learning environment

The association between student's preferred learning environment and success measures were analysed using simple correlation. See Table 4. Overall, the correlations are small with only a few significant relationships but with a general trend for negative rather than positive correlations, implying that students with lower test results tend to prefer a more learner-centred approach. For SI students, this is evident in the *Leadership* scale – students with lower marks want to be told more frequently what they should do. For LTI students, the emphasis is on wanting more *Negotiation* of ideas and concepts and more teacher helpfulness or *Support,* both of which are important components in learner-centred instruction. A similar pattern was observed for the actual learning environment. In general, the finding of Wubbels et al (1991), that enhanced cognitive outcomes are linked to positive attitudes to the class, is not supported in this case but it would be useful to explore further whether learner-centredness assists the retention rates of weaker students.

Table 4: Correlations between cognitive outcomes and perceptions of the preferred learning environment for SI (N = 37) and LTI (N = 52) students. Correlations between –0.2 and +0.2 are not shown (Pearson correlation coefficients)

	SI students		LTI students	
	EXAM	QM TEST	EXAM	QM TEST
Relevance				
Reflection	-0.21	-0.27		
Negotiation			-0.32*	-0.20
Leadership	-0.46**	-0.47**		-0.24
Empathy	-0.23			
Support	-0.26		-0.30*	-0.29*

** $p<0.01$ * $p<0.05$

Conclusions

This study compared two different learning environments in classes undertaking the same subject unit – physics. It has also used multidimensional scaling to reduce complex data and relationships to interpretable two-dimensional spatial maps.

Students perceived the Studio learning environment to offer a high frequency of learner-centred teaching and learning behaviours. Students perceived the Lecture/tutorial learning environment to offer an "average" frequency of similar teaching and learning behaviours. Our interpretation of the spatial maps is that students in the studio classes had a richer understanding of the concept of learner-centredness and were uniformly more satisfied with these aspects of their learning environment than were students in the lecture/tutorial classes, who were less satisfied with what they perceived existed and were less discriminating about what they would prefer.

What does this tell us about the organisation of first year science classes? Current practice favours lecture classes where there are fewer opportunities for teachers to adopt learner-centred practices. This does not mean that good lecturers can't adopt effective learner-centred practices in lectures and tutorials – see Mazur (1997) for example – but rather that lecturing and didactic tutorials fit well with teachers who prefer a "transmissionist" style of teaching. Learner-centredness is not inherent in transmissionst approaches, but is more likely to result if teachers adopt a more constructivist epistemology. For students, the abrupt change from secondary schooling to large-scale education practices may also create the impression of uncaring, remote and unsupportive teachers. If increases in learner-centredness and improvement in student satisfaction are to be educational outcomes in science courses, alternatives to the traditional lecture/tutorial format of instruction seem desirable. A further possibility is for tutors to become more skilled in implementing learner-centred approaches.

The interpersonal qualities of teachers appeared of higher concern to less successful students, regardless of instructional mode. These students wanted more frequent instances where teachers were involved in directing their learning. A possible explanation is that weak students tend to view teachers rather than themselves as the key to their successful physics learning. Weaker students in the lecture/tutorial mode of instruction also wanted more opportunity to discuss and clarify their ideas. While this could reasonably occur in tutorials, the indication is that it did not occur often enough for these students.

Learner-centredness may include students taking responsibility for their own learning, however, the perceived frequency of *Reflective Thinking* (or opportunity for metacognitive activity) rated as only about average for both groups, although both reported that they would prefer more. Despite intentional studio strategies to encourage student reflective behaviour, students seemed relatively unaware of their involvement in such activity or were consciously avoiding it. If students believe that physics knowledge is transferred to them from "authority" figures (such as their teachers), and that learning physics focuses on learning to solve mathematical problems, they may see no reason to reflect on or question how they learn. More effective strategies aimed at developing students' self-reflective practices need to be incorporated in both modes of instruction if the goal of learner-centredness is to be realised for physics students.

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