

Can a Syllabus Change Impact on Students' Perceptions of Science? Fragmented and Cohesive Conceptions of Physics

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In recent decades, the literature paid attention to students' conceptions of the nature of disciplines. This study aimed to investigate how students' cohesive and fragment conceptions of physics changed with a major change in senior high school physics syllabus. We obtained measures of conceptions of physics by utilizing a 20-item questionnaire and triangulated by open-ended responses. The sample was 1979 first year university students from three different years surveyed in their first laboratory session. The first cohort of 780 first year university students had experienced the *old* syllabus in high school and the next two cohorts of 511 and 688 first year university students had experienced a *rejuvenated* high school syllabus. By establishing the reliability and validity we found that there exists a substantial shift in student conceptions of the cohesiveness of physics coinciding with the school syllabus change. This shift was mirrored in qualitative data. Furthermore, students with more previous engagement in physics learning, on the average, demonstrated less fragmented and more cohesive conceptions with the rejuvenated syllabus than with the old syllabus.

Keywords: academic engagement, conceptions, university students, curricular reform, physics education

INTRODUCTION

In higher education, the well-developed presage-process-product model (3P model) of teaching and learning provides a useful framework for understanding the educational context (Biggs, 1987). Within the 3P model factors such as syllabuses, curricula and assessment determine how a discipline area is conceptualized and represented by both teachers and students. From the point of view of 'constructivist'

theories of learning, the representation of the discipline within syllabuses and assessment influences the conceptual frameworks for constructivist learning and the making of meaning (Reigler, 2001). The general question then arises: is a change in the syllabus for a particular subject, or in the wider curriculum, reflected in students' conceptions of the discipline area and is such a change measurable? Specifically, we investigated how a dramatic change in a senior high school syllabus may have influenced student conceptions of the nature of physics as a discipline. The aims were to: 1. develop and check a measurement instrument and associated scale measures; and, 2. examine trends between students' previous engagement with physics learning and their conceptions of the nature of physics at the time of their entry into university studies. The implications for

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State of the literature

- The representation of the discipline within syllabuses and assessment influences the conceptual frameworks for constructivist learning and the making of meaning.
- Students' conceptions of discipline areas are dictated by syllabuses and curricula which can shape the complex epistemological beliefs that are reflected when students debate socio-scientific issues.
- The main issue is to understand what student conceptions are so that they can be considered in designing university teaching and learning.

Contribution of this paper to the literature

- The result of this study supports constructivist notions of learning and education.
- There is ample potential for instruments like the CoPQ to be used in research in order to further explore constructivist processes and to inform teaching and learning.

educational theory and for teaching and learning are discussed.

Examining conceptions of a discipline

The term conception is a broad construct with diverse meanings. It necessarily reflects complex epistemological beliefs with regard to the nature of a discipline. For example the famous physicist Born pondered:

I am now convinced that theoretical physics is actually philosophy. (Max Born, 1882-1970)

In this study we considered the theoretical frameworks for understanding a discipline area as *conceptions of physics*. Prosser, Walker and Millar (1996) studied students' notions of *what physics is about* from answers to the open-ended question: *If you had a friend who had never studied physics before and they asked you to tell them what the study of physics involves, what would you say?* They developed a hierarchical set of categories, which were grouped into a *relatively disconnected focus* and a *connected overview* of what physics is about. The conceptions fall on two sides of a divide between cohesive and fragmented views, with a pronounced jump in complexity and structure between the two. The boundary is a discontinuity rather than a gentle progression from fragmented to cohesive conceptions. The fragmented conception indicates a disjointed view of the discipline, focussing on elements such as topics and equations, with minimal regard for the links,

relationships and associations among those elements. The cohesive conception, on the other hand, indicates a more integrated view, elaborating on the links and associations between elements and reflection on aspects of the nature of the discipline. Booth and Ingerman (2002) found a similar divide when they investigated first year students' experiences of learning physics. Some studies of conceptions in mathematics have produced similar results. For example a conceptions of mathematics questionnaire (Mji & Klass (2001) found a cohesive-fragmented divide. Crawford and others (1994, 1998a) used a phenomenographic approach to qualitatively investigate student conceptions of mathematics in higher education. As with the physics studies (Prosser & Millar 1989; Prosser Walker & Millar, 1996), Crawford and colleagues found a clear divide between cohesive and fragmented conceptions. They extracted items reflecting cohesive and fragmented conceptions and developed scale measures for these conceptions (Crawford, Gordon, Nicholas & Prosser, 1998b).

Why is studying conceptions of a discipline important?

Does it make a difference if students have a fragmented or cohesive conception of a discipline area?

Dahlgren and Marton (1978) arrived at the following conclusion

.... we suggested that several academic disciplines had in fact been generated from a network of well-defined relations between a limited number of basic concepts and principles. It must surely be an essential function of teaching to secure the students' understanding of this basic network of ideas. But in practice, given the many other demands on him, the teacher may well fail to meet individual demands for explanation or clarification. In response, the average student's strategy for coping with the often impossibly rapid pace of teaching sessions is, naturally enough, to try to learn everything by rote. ... the resulting knowledge will be mass of logically and psychologically inconsistent fragments; and the practical usefulness of the individual's efforts will in the last analysis be highly questionable. (p. 34)

Studying the relationships between conceptions of a discipline and approaches to study, Entwistle, Meyer and Tait (1991) identified a group of students that reported a preference for both a deep and a surface approach to learning, and indicated that they held both a fragmented and a cohesive conception of the subject. Such behaviour was termed *dissonant*. The group's dissonant experience of learning is puzzling as it contains what appear to be disparate learning styles and conceptions. Prosser, Trigwell, Hazel and Waterhouse (2000) confirmed the existence of this dissonant group in physics. On assessment tasks, the dissonant group did poorly, while groups labelled *understanding* and *reproducing*

tended to perform better. The understanding group had deep approaches to study and cohesive conceptions of the discipline area, while the reproducing group had surface approaches and fragmented conceptions. In the study reported here, the aim was to understand conceptions of physics and to determine if those conceptions changed with a syllabus change, and not for comparisons with achievement. Beyond academic achievement, educators endeavour to produce scientifically literate citizens who can debate socio-scientific issues that deal with complex, controversial and uncertain questions involving values, technological, economic, ethical, social and political considerations. Students' conceptions of discipline areas are dictated by syllabuses and curricula which can shape the complex epistemological beliefs that are reflected when students debate socio-scientific issues (Albe, 2008). Further, can student epistemological beliefs in one science discipline influence their beliefs in another science discipline? For example, say the chemistry curriculum is contextual. Will students who study chemistry and not physics have tentative beliefs that physics is also contextual as physics and chemistry were presented under the single banner of science in earlier years? The study reported here suggests an affirmative answer.

At a fundamental level, we face the issue of whether we have sufficient science graduates in the workforce (Sharma et al. 2008) as student enrolments in physical sciences are not increasing in proportion to total enrolments. One way of sustaining numbers is to change school curricula. The question is how? In the Australian context, Lyons (2005) notes

the most cogent single force acting against the choice of physical science courses was the culture of school science itself. ... students in this study considered school science to have fewer intrinsically satisfying characteristics than it might have.

Even though the question of whether the change in syllabus has made physics more *intrinsically satisfying* is beyond the scope of this study, this study demonstrates that it is possible to measure changes in students' conceptions of physics.

The senior high school syllabus

Changes to the senior high school syllabuses in the state of New South Wales in Australia (2000 in year 11 and 2001 in year 12) have introduced, in some cases, dramatic shifts in the pedagogy and practice of teaching and learning in the high-school classroom. Across all the sciences a contextual approach, with considerations of relevance to society, ethics, history and culture has been introduced. Furthermore, increased experimentation, gathering information from a range of sources and assessing reliabilities of such data are interleaved with

glimpses of contemporary science in the rejuvenated science syllabuses. Of course, there is a trade-off and each discipline area has dealt with this by reducing some of the syllabus content. The overall objective was to provide a holistic experience of the nature and content of each discipline, together with understandings of its role within society. We expect that students who have studied any senior high school science discipline would have been influenced by the broad aims of the new syllabuses. The Physics Syllabus for the Higher School Certificate (HSC) (Board of Studies, 2002), in particular, has changed from one in which physical theories and standard problem solving are central, to a *rejuvenated* approach in which concepts are emphasised and the subject is placed strongly within a historical and cultural context. There has been debate amongst educators in secondary and tertiary institutions about the effects of those changes; specifically, educators have debated the wisdom of emphasising contextual and conceptual physics at the expense of mathematical derivations and formula-based physics - a *dumbing down* of the content reported by the media (Burke, 2003). Haggis (2006) argues that '*embedded, subjectspecific exploration of different types of disciplinary process is not an argument for 'dumbing down' or an indication of the erosion of standards.*' Rather it is an acknowledgment of diverse ways of knowing within disciplines. For more details on the change in syllabuses see Binnie (2004). From the viewpoint of university physics educators, the main issue is to understand what student conceptions are so that they can be considered in designing university teaching and learning.

METHOD

Materials

The study drew on an expert panel, employing a modified Delphi technique (Clayton, 1997) to review and select appropriate questionnaire items. The descriptions from the phenomenographic categories in Prosser, Walker and Millar (1996) form the foundation for the items of the Conceptions of Physics (CoPQ) questionnaire. Since there is overlap in ways of knowing and thinking in mathematics and physics, items in the Conceptions of Mathematics Questionnaire (Crawford, Gordon, Nicholas & Prosser, 1998b) were also considered. After considerable extended discussions and debates a set of 20 items was generated, 10 of which were intended to represent cohesive conceptions with another 10 for fragmented conceptions of physics (see Table 3 provided further on). A response to each item is recorded on a fivepoint Likert scale, from 'Strongly Disagree' to 'Strongly Agree'.

In addition to the CoPQ two open-ended questions specifically designed to determine students' awareness of physics were included:

Table 1. A comparison of themes for the question: *Much of physics is about the way things move and changes in motion. What do you know about the physics of motion?* There is no statistically significant difference between students who experienced the old syllabus and those who experienced the rejuvenated syllabus in high school.

Theme	Examples	Old syllabus	Rejuvenated syllabus	
		Tally (%)	Tally (%)	Tally(%)
Lists of terms	$F = ma, V = s/t, a = v/t...$ <i>Pendulums and springs...force. Tensions, collisions...</i>	165(51)	223(53)	133(48)
Linking physics ideas	<i>Motion is the base which makes up physics. It is applied to almost everything in physics.</i>	62(19)	64(15)	55(20)
Linking physics to external reality	<i>I know how the earth remains in orbit, ... how police measure speed of cars ... how we can tell whether stars are coming towards us or not.</i>	17(5)	23(6)	17(6)
Little Information	<i>A fair bit</i>	81(25)	110(26)	71(26)
Totals		325	420	276

Q1: Much of physics is about the way things move and changes in motion. What do you know about the physics of motion?

Q2: There is a lot of Physics that relates to the way people communicate with each other. What do you know about this?

The first question is abstract and elicits understandings of a topic in physics – mechanics. While, the second question relates to aspects of everyday experiences and elicits associations between topic areas in the HSC physics syllabus. The first question does not necessarily distinguish fragmented and cohesive conceptions, simply accessing domain knowledge in the area of mechanics. This question was used to determine if students experiencing the different syllabuses had the same mechanics baseline knowledge. The second question should enable us to measure shifts from fragmented to cohesive. It was intended that responses to open-ended questions be used to triangulate, verify or falsify, trends on the CoPQ.

Participants

The participants in this study were 1979 first-year physics students at the University of Sydney, sampled over a period of three consecutive entry years. The first cohort enrolled in first year physics immediately after the last year of the old HSC syllabus, while the next two cohorts enrolled in the two years following the rejuvenated syllabus. Each student was enrolled in one of three classes: *Fundamentals*, *Regular* or *Advanced*. The *Fundamentals* class is for students who have not engaged in learning physics in senior high school or have not been successful. Although the students in the *Fundamentals* class have little background in physics they are relatively high performers, with some who have done well in the highest level of mathematics in senior high school and some ranked among the top ten percent in the state. The *Regular* class is for students who have successfully engaged in learning senior high school

physics, while the *Advanced* class is for those who have done well in high school physics and are also overall high academic achievers with an interest in physics. In general, students in the *Advanced* class have engaged more with physics than those in the *Regular* class by participating in a range of extra activities. The three classes effectively group students according to their previous engagement with physics learning (Tongchai et al., 2009). The differences between the *Fundamentals*, *Regular* and *Advanced* classes can be viewed as a progression in previous engagement with physics learning. The students in the three classes are from a wide range of degree programs ranging from Engineering, through Medical Science to Arts. Physics majors and postgraduate students are drawn from all three classes but the largest fractions continuing with physics are from the *Advanced* class, followed by *Regular* and lastly *Fundamentals*. The three classes are demographically comparable in most aspects, except for gender ratios. Sixty three percent of the *Fundamentals* class is female in comparison to approximately 30 percent in the other two classes.

Procedure

The survey was administered with informed participant consent during the first laboratory session of the first semester of students' university study. Responses obtained so early in the semester should reflect recollections of experiences during the senior high school years. The study ran over three years. The first cohort of 780 included students who had studied the *old* syllabus in high school and the next two cohorts of 511 and 688 included those who had done the *rejuvenated* high school syllabus. The percent response rate was 95% for the old syllabus, 65% for the first year of the rejuvenated syllabus and 85% for the second year. The lower response rates were due to changes in class organisation and the methods employed for questionnaire administration.

Table 2. A comparison of themes for question 2

Theme	Examples	Old syllabus	Rejuvenated syllabus	
		Tally (%)	Tally (%)	Tally (%)
List-like	<i>Optics, telecommunications, waves ...Sound involving pitch, frequency</i>	60(26)	59(25)	96(33)
Vague linking of ideas	<i>Physics keeps up to date with technology that can improve communications</i>	26(11)	-	2(0)
Explicit linking focusing on the role of physics	<i>Physics is highly involved with the communications between people as this often requires a physical medium as well as the transfer of energy, for example in sound waves or in electronics.</i>	3(1)	59(25)	71(25)
Little information	<i>A fair bit</i>	145(62)	119(50)	122(42)
Totals		234	237	291

Analysis

A range of analyses was employed to explore the data, test reliability and validity of the measures and examine trends in the responses. The measurement properties of the CoPQ were examined thoroughly during data exploration. Exploratory and confirmatory factor analyses were used to examine the data structure and to validate the *cohesive* and *fragmented* factors. Reliability analyses were also conducted. A comparative analysis of the three year cohorts was then used to determine any changes in student conceptions that occurred over time and/or with changes in the physics syllabus. Responses to questions 1 and 2 were analysed using the following categorization process. Three researchers independently coded thirty random responses. At a meeting, common initial codings were agreed and an initial categorization of codes was also developed. The number of responses examined was then increased until coding saturation was reached and final codes and categories were determined. The inter-researcher percentage agreement was 80% or better. Based on the codings, the emergent categories were collapsed into four final themes for this report.

RESULTS

Qualitative findings

We present the results for classes who had *done* senior high school physics. For each year and question, sampling was stopped when codings stabilized – both in terms of the number of codes and percentages of responses across the categories. Thus the number of responses examined each year varies. The findings for each open-ended question are presented separately. The themes for Question 1, examples of student responses that fell into each theme and numbers of students for each theme are given in Table 1. As anticipated, the data have very similar distributions. There is no statistically

significant difference in the distributions across the themes for the three years ($\chi^2=3.7$, $df=6$, $p=0.72$).

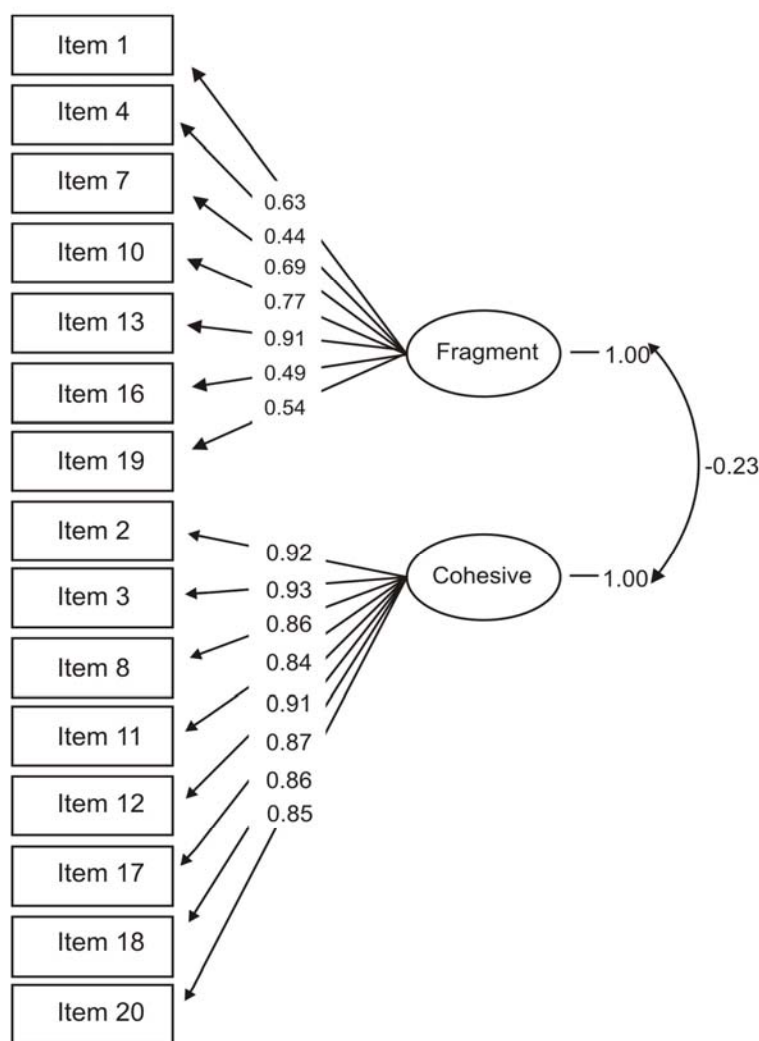
Table 2 shows a comparison of the themes (i.e. examples of student responses that fell into each theme and numbers of students for each theme) for question 2: *There is a lot of Physics that relates to the way people communicate with each other. What do you know about this?* There is a statistically significant difference between students who experienced the old syllabus and those who experienced the rejuvenated syllabus in high school. There is a statistically significant difference in the distributions across the themes for the three years ($\chi^2=172$, $df=6$, $p<0.05$). The most dramatic contrast between the students experiencing the old and rejuvenated syllabuses is in responses commenting explicitly on the role of physics: done by only 1% of the students experiencing the old syllabus but by 25% of the students experiencing the rejuvenated syllabus. By contrast, a small but significant group of responses classed as a vague linking of ideas were seen in the old syllabus cohort but almost disappeared after the introduction of the new syllabus. There was also a decrease in the number of responses classed as having little information.

Quantitative findings

Exploratory factor analysis

The response distribution for each item on the Conceptions of Physics Questionnaire (CoPQ) was examined. The distributions from the fragmented set were similar for the old and rejuvenated syllabuses while those from the cohesive set showed trends in the same direction as that of the qualitative findings more cohesive for the rejuvenated syllabus.

As a check on the validity of the selection of items for each of the fragmented and cohesive scales, we did an exploratory factor analysis, both for the total sample and by year. If the cohesive and fragmented scales are



Chi-Square=1588.19, df=89, P-value=0.00000, RMSEA=0.091

Figure 1. Standardized coefficients for the two-factor model of the Conceptions of Physics Questionnaire

Table 3. Items on the Conceptions of Physics Questionnaire with respect to the two scales, fragmented and cohesive conceptions of physics

Fragmented
1. For me, Physics is just the study of facts and formulas.
4. Physics is about doing problems.
7. What Physics is about is finding answers to problems through the use of different formulas.
10. Physics is just a lot of rules and equations.
13. Physics is just about playing around with equations and working out problems.
16. Physics is a subject where you manipulate formulas to solve problems.
19. Physics is the study of the world by solving mathematical problems.
Cohesive
2. Physics is a theoretical and experimental framework we use to help us understand the world.
3. By doing Physics we can generate new understanding.
8. I think Physics provides an insight into the complexities of our reality
11. Physics is like a universal language which allows people to describe and understand the universe.
12. In Physics you study the physical world around us and the way it works.
17. Physics is a logical system which helps explain the things around us.
18. Physics is a set of theories that have been devised over years to help explain and investigate matters in the world.
20. Physics is a process of making and testing models about the way things work in the universe.

sound than they should show consistent item factor loadings and be stable. In order to extract meaningful factors we used (a) iterative maximum-likelihood estimation procedure, (b) extraction of factors based on multiple checks - Scree test and Kaiser criterion (eigen values), (c) oblique (direct oblimin) structure rotation and (d) comparison of unrotated and rotated solutions (Cattell, 1978; Gorsuch, 1983; Preacher & MacCullum, 2003). In all cases data met the requirements; Kaiser-Meyer-Olkin measure of sampling adequacy was greater than or equal to .857 and Bartlett's test of sphericity was 3387 or better ($p < .0001$). Based on eigen values and the Scree test, two factors were extracted and factor solutions for rotated and unrotated solutions were similar. Thus a clear and robust factor solution identifying cohesive and fragmented conceptions of physics was identified. As an aside we note that the use of direct oblimin rotation does not assume orthogonal or independent factors but does require any inherent correlation to be small. Large correlations would suggest that the scales could be better interpreted as a single factor. The correlation between the two scales in our study is negative and small enough to support two factors.

Table 3 shows the items on the CoPQ with respect to the factors. The loadings were largely as expected according to the conceptual basis of the items. Consequently, our data and the conceptual base support a stable two-factor solution. There were five indeterminate items which were broad statements referring to the role of physics in the world, universe or everyday life.

Confirmatory Factor Analysis

Confirmatory factor analysis was used to verify the factor structure of the 15 items of the CoPQ and to examine the relationship between observed variables (items) and their underlying latent constructs (fragmented and cohesive scales). Confirmatory factor analysis was conducted using LISREL 8.8 software (Jöreskog & Sörbom, 2006) and maximum likelihood was used as the method of estimation. Figure 1 shows the model and parameter estimates for the total sample.

It is known that χ^2 statistic is sensitive to the sample size and may not be appropriate for large sample sizes (Bentler & Bonett, 1980; Fan, Thompson, & Wang, 1999). Therefore we considered several other fit indices: Comparative Fit Index (CFI; Bentler, 1990), Normed Fit Index (NFI; Bentler & Bonett, 1980), and Root-Mean-Square Error of Approximation (RMSEA; Steiger, 1990). Values of CFI and NFI over 0.90 indicate good fit (Kline, 1998). Browne and Cudeck (1992) suggest that RMSEA values less than 0.05 indicate close fit and models with values greater than 0.10 should not be employed.

Confirmatory factor analysis was also conducted by year; see Table 4 for fit indices. Values of CFI, NFI and RMSEA indicate a good fit. Moreover, loadings of each item on corresponding latent variable (fragmented or cohesive) show reasonable sizes to support the two-factor model of the CoPQ.

Table 4. Fit indices for confirmatory factor analysis of incoming university students over three years; the students who had experienced the old high school physics syllabus and the two subsequent years of students who had experienced the rejuvenated syllabus.

Fit Indices	Old syllabus	Rejuvenated syllabus		All
CFI	0.974	0.948	0.942	0.970
NFI	0.964	0.934	0.929	0.968
RMSEA	0.0543	0.0799	0.0770	0.0910
(90% confidence intervals)	(0.0476 - 0.0611)	(0.0718 - 0.0881)	(0.0701 - 0.0841)	(0.087 - 0.095)

Table 5. Internal consistency of the fragmented and cohesive scales for incoming university students over three years; the students who had experienced the old high school physics syllabus and the two subsequent years of students who had experienced the rejuvenated syllabus.

Class	Fragmented			Cohesive		
	Old syllabus	Rejuvenated syllabus		Old syllabus	Rejuvenated syllabus	
Advanced	.809	.728	.754	.723	.770	.641
Regular	.822	.806	.781	.755	.810	.756
Fundamentals	.826	.716	.792	.809	.840	.813
All	.837	.790	.790	.778	.814	.754
	n=780	n=511	n=688	n=779	n=506	n=687

Reliability

The reliability of the scales was determined using Cronbach's alpha, see Table 5. The reliabilities are adequate with alpha in the range of .716 to .840, except for one unexplained anomalous value of .641. Reliability measures such as split halves and Guttman's reliability coefficient confirmed the adequacy of the scales.

Comparison between years and classes

To determine if the changes in the school physics syllabus are reflected in students' conceptions of physics

we examined the distributions for the scales by year and class, see Figure 2a and b. However, recall that the Fundamentals class did not do senior high school physics but most have done other sciences. So the question of whether a systematic syllabus change across the sciences exhibits itself in students' perspectives of a science subject that they have not done can also be explored. We notice four points, three with regard to the fragmented scale and one pertinent to the cohesive scale. First, on the fragmented scale, for the students exposed to the old syllabus, the mean of the Advanced class is higher than that of the Regular which in turn is

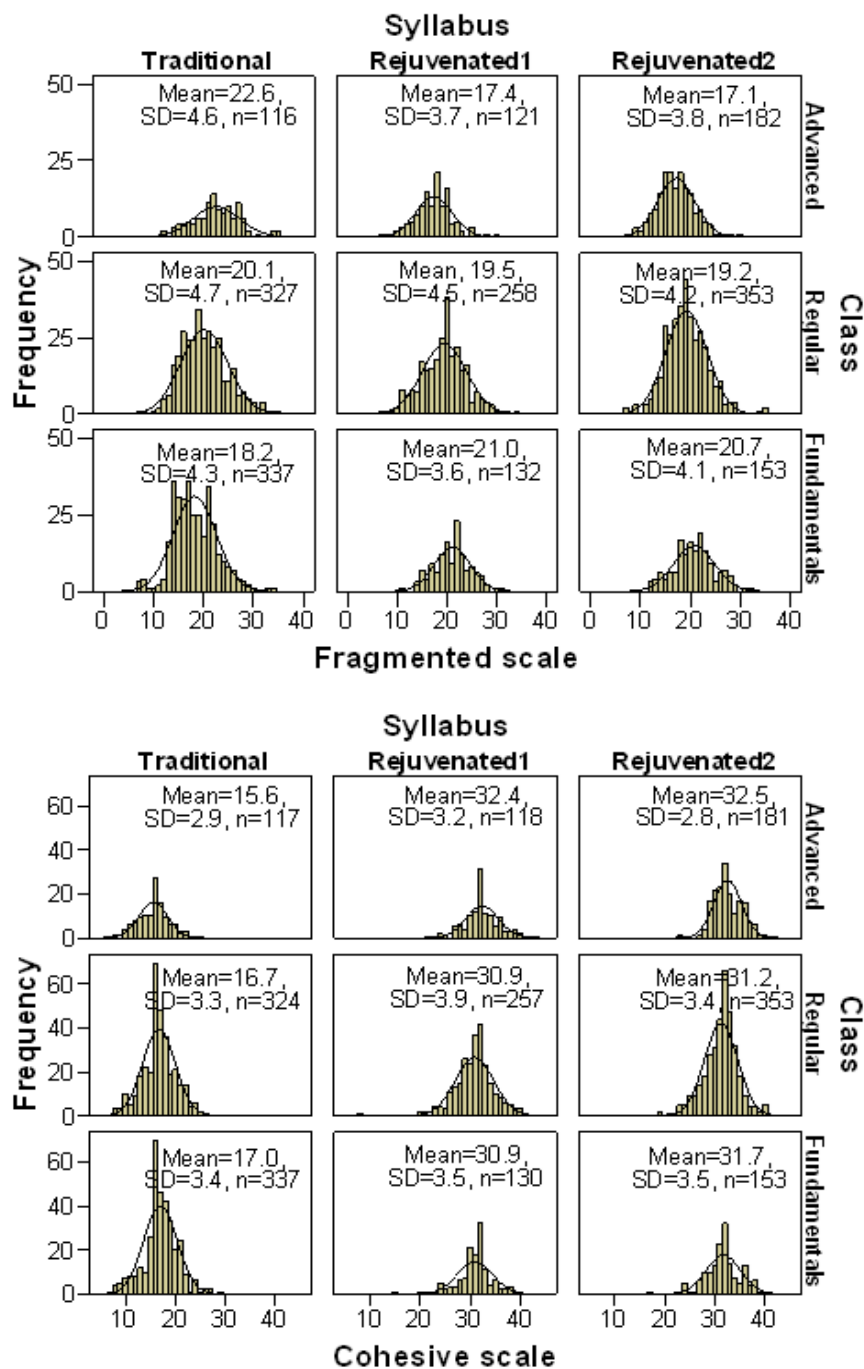


Figure 2. Distributions for the fragmented (2a) and cohesive scales (2b) for incoming university students over three years. The first year cohort experienced the old syllabus and the next two year cohorts the rejuvenated syllabus.

higher than that of the Fundamentals. This trend in the means is reversed for the rejuvenated syllabus. The implication is that with the old syllabus more previous engagement with physics learning on average increased fragmented conceptions of physics while with the rejuvenated syllabus more previous engagement reduces fragmented conceptions. Second, the mean for the fragmented scale for the Advanced class exposed to the old syllabus is higher than those of the Advanced classes exposed to the rejuvenated syllabus. Using one way-ANOVA, we confirm this trend ($F=74.312$, $df=2$, $p<.01$). The implication is that with the rejuvenated syllabus, the Advanced class on average has a less fragmented conception of physics. Third, the means of the fragmented scale for Regular is not different for the three years ($F=3.791$, $df=2$, $p=.023$). The implication is that fragmented conceptions for this group are not influenced by syllabus change. Fourth, on the cohesive scale there is a shift in the distribution towards more cohesive conceptions corresponding to the change from the old syllabus to the rejuvenated syllabus. The implication is that there is a dramatic shift towards more cohesive conceptions of physics as a result of the syllabus change. Furthermore a systematic change across the sciences is reflected in students' perspectives of the science subject they have not studied, physics in this case.

To synthesize our results, we mapped the trends in the two scales for the classes as shown in Figure 3. In Figure 3, the old syllabus has the classes with on average more fragmented and less cohesive conceptions as high achievers. The implication is that assessment could be rewarding such conceptions in the old syllabus. On the other hand, in the rejuvenated syllabus the classes with on average less fragmented and more cohesive conceptions are high achievers (see figure 3). The interplay between total learning experience, syllabus and assessment emerges in our study and needs further study.

Further analyses compared student gender using independent samples *t*-test. No significant gender differences in mean scores on the two factors were observed, even when considering different year cohorts and classes.

DISCUSSION

We had two aims: to establish and validate the use of the CoPQ and to use the CoPQ to explore whether students conception of physics may, or may not, have changed in response to different school physics syllabuses.

We have developed and validated the CoPQ by combining qualitative student responses, expert validation and appropriate statistical analyses. There is pleasing alignment between the qualitative and quantitative elements of our study. Factor analysis has confirmed the dichotomy of cohesive and fragmented conceptions of physics. The fragmented scale has 7 items and the cohesive has 8; providing an adequate number of items for each scale.

Using the CoPQ the transition in high school physics syllabus is reflected in a shift from weaker cohesive conceptions of physics to, stronger cohesive conceptions of physics. Our findings are in line with Biggs's (1993, 1999) theory of constructive alignment, in which students' perceptions and experiences of the educational environment play an important part in their learning. Furthermore, the shift in our study cohorts' conceptions of physics illustrates the very dynamic nature of students' views. This is in keeping with Karimiloff-Smith's (1992) theory on the development of representations or concepts in younger children. Her Representational Redescription Model, and supporting empirical study, sets out a theoretical position that suggests that children's existing conceptual knowledge is developed from low level implicit representations into more abstract and stable representations through a redescription process based upon experience and knowledge. Our findings here, in an older age group, demonstrate the malleability and, perhaps, pragmatic ability, of students to formulate their cognitive conception of physics based upon formal curriculum they are presented with. It is, in fact, evidence of the formative power of education.

What sort of experience, or knowledge, contributed to the shift in conceptions that we have seen? To illustrate the differences in the syllabuses we draw on the state-wide examination papers for senior high

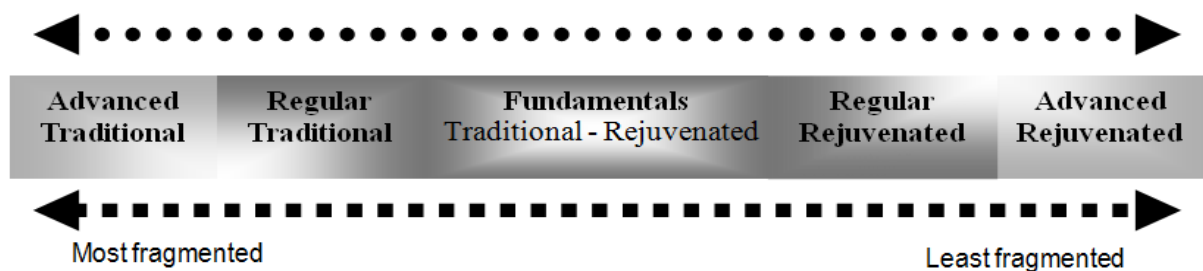


Figure 3. A map of the trends in the two scales for the classes exposed to the traditional or the rejuvenated syllabuses.

school physics. The students exposed to the old syllabus had to predominantly calculate number answers with 15% of questions requiring explanations of physical phenomena such as the following

Using the motor effect, explain briefly how this meter operates. Why are the poles of the permanent magnet curved around the armature?

Later cohorts educated under the rejuvenated syllabus encountered questions requiring calculation of numbers as well as questions such as the following.

“How does Einstein’s Theory of Special Relativity explain the result of the Michelson-Morley experiment?”

and;

“In the late nineteenth century Westinghouse and Edison were in competition to supply electricity to cities. This competition led to Edison holding public demonstrations to promote his system of DC generation over Westinghouse’s system of AC generation. Propose arguments that Westinghouse could have used to convince authorities of the advantages of his AC system of generation and distribution of electrical energy over Edison’s DC supply.”

The shift in examination questions requires students to integrate different curricular materials and to apply physics thinking to real-life problems, perhaps even within a historical context. Albe (2008) argues that debating such socio-scientific issues shapes students’ epistemological beliefs and strategic considerations. Wei and Thomas (2006) have investigated how the chemistry syllabus in Chinese Junior Secondary Schools has changed from 1978 to 2001. Those changes were gradual rather than sudden as in New South Wales, but they parallel the philosophical changes in the HSC science syllabuses. Because the changes were gradual it was impossible to measure changes in the same way that we have done. The HSC rejuvenated syllabus and associated examination questions require linking within physics and exploration of the broader role of physics. Those requirements may account for the shifts measured in our study.

The shift in conceptions illustrated in this study lies comfortably within broad constructivist educational theory, which proposes that learning is an active process in which learners develop new ideas or constructs based upon personal experience and knowledge (Bruner, 1990). This ‘construction’ can apply not only to curriculum components, but also to conceptions of the discipline itself. In some of his earlier work Bruner proposed that one of the critical elements in learning is the requirement for a body of knowledge to be structured so that it is most easily grasped by the learner (Bruner, 1966). Although it is apparent that syllabus change has coincided with a measurable shift in student conceptions, it remains to be seen whether the shift in syllabus has effectively structured the knowledge in order to optimize learning. We can only reflect that the structuring of the new syllabus is in line with

contemporary views of physics and of learning in general (Sadler, Barab, Scott, 2007). There is potential for future research to explore the impact of conceptual change further and to examine its relationship with teaching and learning practice and also assessment performance.

This study had the rare opportunity to observe the impact of dramatic curriculum change. However, our observations would be strengthened further had the stability of the CoPQ been established in several cohorts before the senior high school syllabus change occurred. Furthermore, the sample is not representative of all students who did senior high school physics studies, being drawn from one university only. In future studies, the meaningfulness of the CoPQ findings needs to be established by further research on their alignment with the quality of student work and student academic achievement.

As a final note we can also reflect upon the experience of students who participated in this study. By completing the CoPQ students took time to consider their own views of the discipline. Constructivist theory suggests that such reflection is itself formative in learning and is a worthy educational activity that may help students to formulate their conceptual structures.

CONCLUSION

In a broad sense this study has illustrated the power of educational experience to impact upon individuals’ conceptions of the nature of the world around them. As such it supports constructivist notions of learning and education. There is ample potential for instruments like the CoPQ to be used in research in order to further explore constructivist processes and to inform teaching and learning. Research which examines disciplinary conceptions goes to the heart of epistemological belief and future studies may provide further insight into these complex, but rarely articulated, conceptual frameworks that drive our personal learning.

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