Student Approaches to Learning in Physics – Validity and Exploration Using Adapted SPQ

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Abstract: The aim of this study was to investigate an adaptation of the Study Processes Questionnaire for the discipline of physics. A total of 2030 first year physics students at an Australian metropolitan university completed the questionnaire over three different year cohorts. The resultant data has been used to explore whether the adaptation of the questionnaire is justifiable and if meaningful interpretations can be drawn for teaching and learning in the discipline. In extracting scales for deep and surface approaches to learning, we have excised several items, retaining an adequate subset. Reflecting trends in literature, our deep scale is very reliable while the surface scale is not so reliable. Our results show that the behaviour of the mean scale scores for students in different streams in first year physics is in agreement with expectations. Furthermore, different year cohort performance on the scales reflects changes in senior high school syllabus. Our experiences in adaptation, validation and checking for reliability is of potential use for others engaged in contextualising the Study Processes Questionnaire, and adds value to the use of the questionnaire for improving student learning in specific discipline areas

Keywords: *Student approaches to learning, learning in disciplines, university physics education*

Introduction

Since the mid 1960's a series of inventories exploring student learning in higher education have been developed based on learning theories, educational psychology and study strategies. For reviews of the six major inventories see Entwistle and McCune (2004)

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and Biggs (1993a). As can be seen from the reviews, these inventories have two common components. One of these components is related to study strategies and the other one is about cognitive processes. Moreover, these inventories usually have similar conceptual structures and include re-arrangement of the items (Christensen et al., 1991; Wilson et al., 1996).

In the current study, as one of these inventories, The Study Processes Questionnaire (SPQ) has been selected to be adapted for use in physics. The SPQ is integrated with the presage-process-product model (3P model) of teaching and learning (Biggs, 1987). Several studies have successfully used the SPQ across different cultures and years to compare students' approaches in different disciplines (Gow et al., 1994; Kember & Gow, 1990; Skogsberg & Clump, 2003; Quinnell et al., 2005; Zeegers, 2001). Moreover, several other researchers used modified version of the SPQ at their studies (Crawford et al. 1998a,b; Fox, McManus & Winder, 2001; Tooth, Tonge, & McManus, 1989; Volet, Renshaw, & Tietzel, 1994). For example, Volet et al (2001) used a shortened SPQ included 21 items to assess cross cultural differences. Fox et al (2001) modified the SPQ and tested its structure with confirmatory factor analysis. In their study the modified version of the SPQ had 18 items, and this shortened version had same factor structure as the original SPQ. In another study, Crawford et al. (1998a, b) adapted the SPQ for the discipline of mathematics. That adapted questionnaire was named as Approaches to Learning Mathematics Questionnaire.

Three different approaches of the students to learning are represented in the SPQ: surface, deep, and achieving approaches. Idea of approaches to learning was presented by Marton and Säljö (1976) and further discussed by several other researchers (eg. Biggs, 1987; Entwistle & Waterston, 1988). Basically, surface approach indicates that the students' motivation to learn is only for external consequences such as getting the appreciation of the teacher. More specifically, it is enough to fulfill course requirements for the students with surface approach. On the other hand, a deep approach to learning indicates that the motivation is intrinsic. This approach involves higher quality of learning outcomes (Marton & Säljö, 1976; Biggs, 1987). Students with deep approach to learning try to connect what they learn with daily life and they examine the content of the instruction more carefully. On the other hand, achieving approach is about excelling in a course by doing necessary things to have a good mark. However, current study is not focused on this approach. Only the first two approaches were included in the adapted SPQ.

Inventories like the SPQ are used in higher education because of several reasons. Such inventories can help educators to evaluate teaching environments (Biggs, 1993b; Biggs, Kember, & Leung, 2001). Moreover, with the use of these inventories, university students often relate their intentions and study strategies for a learning context in a coherent manner. On the other hand, the SPQ is not a discipline specific inventory. It can be used across different disciplines. However, in a research study, if the research questions are related with the common features of learning and teaching within 3P model framework, the SPQ can be used satisfactorily for all disciplines. But, a discipline specific version of the SPQ is required if resolution of details specific to a discipline area is necessary for the research questions. Moreover, in order to reduce systematic error and bias that can be resulted from students in different discipline areas; a discipline specific version may be required. As a community of educators, we are aware that thinking, knowing, and learning processes can differ across discipline areas. A direct consequence of this acknowledgement is the need to understand and model learning in specific discipline areas, such as by adapting the SPQ. However, for the theoretical framework to be valid the conceptual integrity of the inventory must be maintained.

This paper reports on how the SPQ has been adapted for physics. The teaching context is first year physics at a research focused Australian university where students are grouped according to differing senior

high school experiences into Advanced, Regular, and Fundamentals streams.

We report on the selection of items for the deep and surface scales and reliability and validity analyses. A comparison of the Advanced, Regular and Fundamentals streams is carried out to ensure that interpretations associated with the deep and surface scales are meaningful. This is a stage of a large-scale project. The project aims to understand and improve student learning based on the deep and surface approaches to learning inherent in the 3P model (Marton & Säljö, 1976; Biggs, 1987).

The study

As mentioned before, The SPQ has been designed for higher education; however, this questionnaire is not discipline specific. Therefore, in this study, we adapted the SPQ to physics for the following reasons: (1) The first year students have confusions about university studies when they come to university (White et al., 1995). This can lead to misinterpretation of the items. However, specific items related to physics can reduce these misinterpretations. For example students enrolled in a general science degree would view questions related to employment differently to those in professional degrees, and the students we have surveyed are from a range of degree programs. (2) In order to compare the students from the different discipline areas, we need discipline specific inventories. (3) We believe that there are contentious items in the original SPQ and aspects that are specific to physics. For example the use of "truth" in the following item was strongly challenged by a group of physicists validating the questionnaire.

While I realize that truth is forever changing as knowledge is increasing, I feel compelled to discover what appears to me to be the truth at this time (Biggs, 1987, p. 132).

The item was changed to the following, more in line with the post-positivist paradigm and agreeable to physicists.

While I realize that ideas are always changing as knowledge is increasing, I feel a need to discover for myself

what is understood about the physical world at this time.

One could argue that this is an issue of clarifying the item rather than being specific to physics. However, to our knowledge the clarity of this item has not been debated in literature.

Just after we commenced this study in 2001, we became aware that Biggs et al (2001) had produced a revised Study Processes Questionnaire (R-SPQ- 2F). However, it was too late for our study and we did not switch midway. There are four main differences between the SPQ and the R-SPQ-2F; first, the removal of all items on employment after graduation; second, increased emphasis on examination; third, removal of words that imply specificity; and fourth exclusion of the contentious achieving factor identified by Christensen et al., 1991. We focus on the deep and surface approaches and not on the strategy and motive sub-scales as these are not pertinent to our larger study. The SPQ deep and surface scales, in particular, have been shown to be robust (see for example Burnett & Dart, 2000).

The participant of the current study was from a university in New South Wales, Australia. Students are provided three basic physics units in the School during their first semester of university: Fundamentals, Regular or Advanced. Students are divided into these three groups of physics units based on their senior high school physics backgrounds. The students from the Fundamentals unit have done no physics in senior high school or have done poorly. On the other hand, in the Regular unit, there were the students had scored high grades in senior high school physics. The last unit, the Advanced unit, is suitable for those who have done extremely well overall in physics during all their years in senior high school.

The three physics units that students can register in are for the degree programs in Engineering, Medical Science and Arts. Students who intend to major in physics as well as postgraduate physics students are selected from those enrolled in all three basic physics course in their first semester at university. The largest proportion of students of physics major is from the Advanced

stream, followed by those in the Regular stream, and finally the Fundamentals stream. The data was collected from these streams from 2001 to 2004. From 2001 to 2004, the high school physics syllabi and assessment system was changed in the state of New South Wales in Australia. The details of the changes can be seen in Binnie (2004). Due to these changes, the 2004 cohort of students in this study were instructed using a different curriculum.

Within the above context, we have adapted the SPQ to generate a Study Processes Questionnaire for Physics (SPQP). The research questions addressed in this paper are as follows.

(a) How do the factor solutions for the SPQP compare with those of the SPQ?
(b) Is the SPQP reliable and valid?
(c) Are the scales robust enough to reflect detail in senior high school syllabus change?
The answers to the research questions will determine if the SPQP is a reliable and valid measure of student approaches to learning physics in our context.

Method

Revising the items for the SPQP

We have adapted the SPQ by simply inserting the word "physics" in some items and making substantial changes to others. The adaptations are based on our experiences of student responses to open-ended questions and discipline knowledge, and have been extensively discussed amongst a group of physics educators. The adaptations are of the types listed below. (See appendix A for all items and the types of adaptations.)

Type 0: No change
Type 1: A simple insertion of terms such as "physics", "studying physics".
I find that at times studying gives me a

feeling of deep personal satisfaction.
I find that at times studying physics gives me a feeling of deep personal satisfaction.
Type 2: A substantial change in wording that can change the meaning, without intending to.
I usually become increasingly absorbed in my work the more I do.
When studying physics, I become increasingly absorbed in my work the more I do.
Type 3: An intentional change in meaning.
My studies have changed my views about such things as politics, my religion, and my philosophy of life.
My studies in physics have challenged my views about the way the world works.

The number of items corresponding to each Type of change is displayed in Table 1, as are the number of items selected from each Type for inclusion in the SPQP. Type 1 items were more useful in generating the items used in the SPQP.

Administering the SPQP

The SPQP was administered at the beginning of the first semester to students in the Advanced, Regular and Fundamentals streams in 2001, 2002 and 2004, respectively.

On the questionnaire, the students were requested to indicate their level of agreement with each item on a Likert scale with the options of *Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree*. Response rates of 2001, 2002, and 2004 cohorts was 95%, 65%, and 85%, respectively. Except 2002 cohort, the response rates were satisfactory. The main reasons of the lower response rate of 2002 cohort were the changes in class organization and questionnaire administration. Over these

Table 1. *The number of items in each Type and the number of items from each Type retained for the SPQP*

Type	Number of items	Items selected for the SPQP
T0	3	0
T1	15	10
T2	3	2
T3	7	4

three years, a total of 2030 first year physics student were responded the SPQP: 63 percent of students in the Fundamentals stream was female, and about 30 percent of them was females in the Regular and Advanced streams. Nevertheless, the three streams are similar in other respects. The sample size of 2030 is large enough to access the natural variance within the diverse population. However, due to missing answers some of the cases were excluded from the analysis. These exclusions were only about 3% of the whole sample. Therefore, we can say that this missing data did not affect the overall results.

Data Analysis Methods

Following analyses were carried out to answer research questions.
(a) Both exploratory and confirmatory factor analyses were performed to validate the two-factor solution: the deep and surface scales.
(b) Cronbach's alpha coefficients were calculated to determine the reliability for the deep and surface scales for the complete data set and for each stream.
(c) ANOVA and boxplots were used to determine if the SPQP is able to differentiate between the three streams and changes in syllabus.

Results

Factor analysis

In order to gain construct related evidence for the validity of the SPQP, exploratory and confirmatory factor analysis were conducted. Exploratory factor analysis (EFA) was carried out by using principal components as factor extraction method with quartimax, an orthogonal rotation. The complete data set was included in this analysis. Before proceeding to interpret the results, each item was checked for normality and sphericity. In order to check multicollinearity, the correlation matrix was examined. In terms of multicollinearity, we expect the items to be intercorrelated; however, these correlations should not be so high (0.90 or higher), which

causes to multicollinearity and singularity. The intercorrelation was checked by Bartlett's test of sphericity. This test showed that the correlation matrix is not an identity matrix. Moreover, multicollinearity was checked with the determinant of the correlation matrix. The determinant was more than 0. This showed that there is no multicollinearity (Field, 2000). Extraction of factors was based on two criteria: Scree test and Kaiser criterion (eigen values). Based on eigen values and the Scree test, two factors, which accounts for 48% of the variance, were extracted. The items with factor loadings of less than .4 were excluded from the further analyses (Field, 2000). Appendix A shows the two-factor solution for all items including loadings. Those that were retained for the SPQP are starred – 10 items form the deep scale and 6 items the surface scale.

According to the results of the EFA, we note that the deep scale is in better agreement with Biggs's deep scale than the surface scale - there are more "usable" items on the deep scale than on the surface scale.

After having results of the EFA, confirmatory factor analysis (CFA) was performed. This second step of the factor analysis helped us to ensure the factor structure of the SPQP (see Figure 1). Maximum likelihood (ML) was used as the method of estimation at the CFA. The results of the study showed that relative chi-square, which is the "chi square/degree of freedom" ratio is 3.1. Moreover, RMSEA and CFI were found to be 0.07 and 0.69 respectively. According to Browne and Cudeck (1992), RMSEA values less than 0.05 indicate close fit and models with values greater than 0.10 should not be employed. Here, RMSEA indicates moderate fit of the model whereas relative chi-square indicates good fit. However, the CFI should be over 0.90 to have good fit. Nonetheless, we can say that the first two indices support this two-factor model of the SPQP and indicate moderate fit.
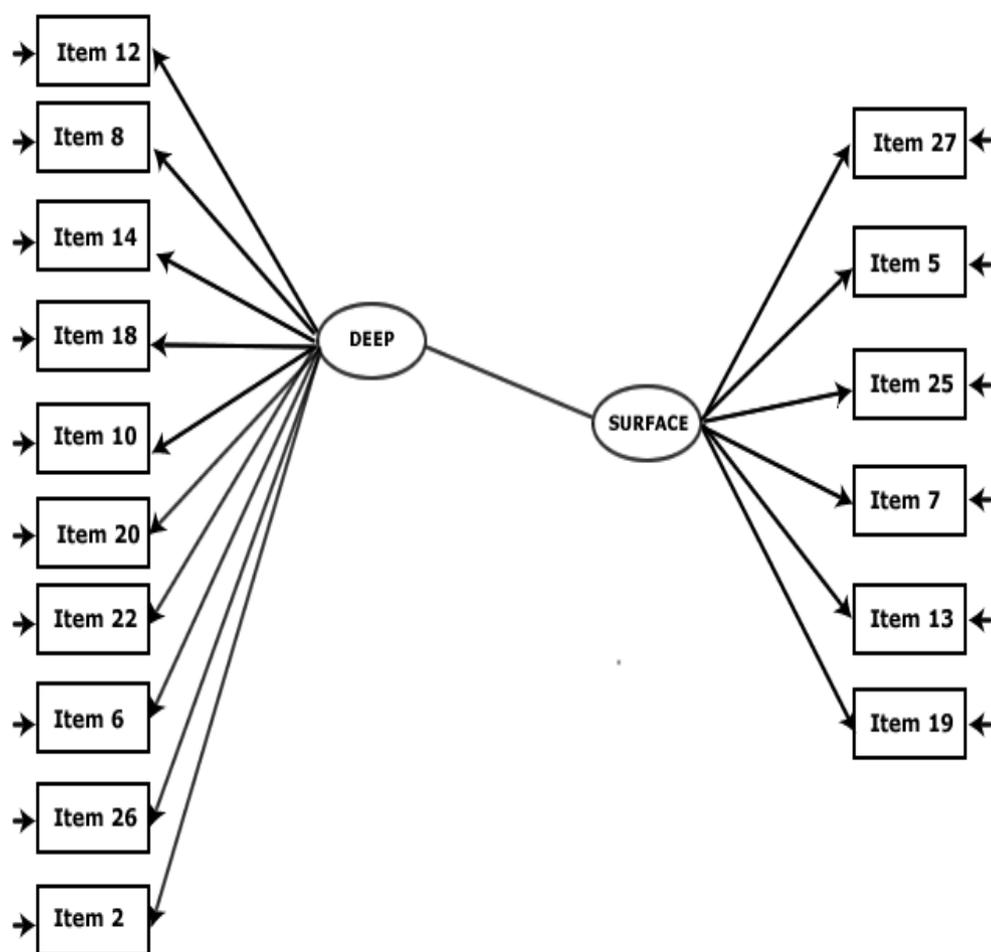
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Figure 1. *Validated two-factor structure of the SPQP.*

Reliability of the SPQP

Cronbach alpha coefficients of each scale were calculated for each stream and whole data. The results are shown in Table 2. It is apparent that the surface scale has the lowest Cronbach alpha coefficients at each stream. Similar findings were also reported at other studies (Biggs, 1987; Biggs et al, 2001; Wilson and Fowler, 2005). The foundational efficacy of these scales, given such low reliability, is questionable. However, in our study higher levels of internal consistency were apparent (lowest α =.61).

Comparing reliabilities across streams, students who have less experience with physics report surface approaches more reliably than students with more experience. On the other hand, students who have more experience with physics report deep approaches more reliably than those who have less experience. Considering reliabilities within streams, the Fundamentals students report deep approaches as reliably as surface

Table 2. *Reliability given by Cronbach's alpha of the deep and surface scales of the SPQP for the different streams.*

SPQP scale	Advanced n=417	Regular n=935	Fundamentals n=618	All students n=1970
Deep (10 items)	.904	.853	.821	.863
Surface (6 items)	.610	.715	.810	.738

approaches with values greater than 0.80, while the Advanced students report very different reliabilities for the two scales. The trends are not surprising since Advanced students would tend to be more confident in content and study strategies.

The above trends also raise the question: *Are the persistently low reliabilities noted for the surface scale due to student 'behaviours' or poor items on the inventory?* An adequate reliability measure for the surface scale for the Fundamentals stream α > .80, one that is similar in magnitude to that of the deep scale, implies that there is internal consistency amongst the items for each scale for this group of students. We note that the Fundamentals students have experienced junior high school physics, and are doing concurrent science and mathematics subjects at university. University students tend to have high internal coherence among learning components, intentions and study strategies and are able to adapt their ideas of knowledge and study methods to their expectations of studying in a particular context. The internal coherence is demonstrated in the reliability scores. So why are the reliabilities for the surface scale as low as 0.61 for the Advanced stream? Is it because the nature of the surface approach is different for the Advanced and Fundamentals streams, requiring possibly different items? Or is it because the Advanced students adapt their surface approaches in diverse ways, hence report this scale less reliably? Answers to such questions will indeed add to our understanding of student learning.

ANOVA and Boxplots

To determine if the SPQP is able to differentiate between the three streams, item and scale means were compared using one-way ANOVA.

When comparing the means of the three streams for each item on the SPQP, the assumption of homogeneity of variances underpinning ANOVA was tested using Mulachy's test of Sphericity. Items A5, A13 and A25 were excluded from ANOVA because they violated the assumption of sphericity. This does not affect their use on the SPQP scales. The results of ANOVA showed that there is a significant difference among the SPQP scores of the students from Fundamentals, Regular, and Advanced streams for both surface and deep scales ($p < .05$).

There is a debate among the researchers to use ANOVA with the ordinal data mainly because of the normality concern. As stated in Glass, Peckham, and Sanders (1972), violation of normality is not fatal to the ANOVA. Moreover, performing ANOVA with the ordinal data, likert type items in this case, is a controversial issue among the researchers. Here, we have a big sample and this surely increases the power of the test. Therefore, failure to meet normality assumption will not affect the results of the ANOVA. Moreover, we performed Kruskal Wallis test as non-parametric alternative of the ANOVA. The results of that test supported the results of the ANOVA given above.

Moreover, in order to investigate if SPQP is robust enough to be able to differentiate changes in syllabus even when sum of the items is used instead of factor scores, boxplots were checked (see Figure 2). The boxplots show a sequence for each scale with the first panel representing the factor scores, the second panel the simple sums of the items scores for the SPQP and the third panel the simple sums of all 16 item scores that should have loaded on each scale. We note two important features. First, the three panels representing the deep scale are sufficiently similar implying that if an adaptation such as that in this study is made, the sums of the 10 SPQP item scores, and indeed all 16 items scores provide a reasonable measure of deep approaches to learning. However, this is not so for the surface scale, while the sum of the 6 SPQP item scores provides a reasonable measure of surface approaches to learning, the sum of all 16 items does not do so. This raises concerns regarding the surface scale and is a reflection of the low reliabilities for the scale.

Discussion

As we are particularly interested in issues to do with learning physics, the rationale and manner in which items were modified and the SPQ adapted are discussed in detail. The advantages of adapting an established, well
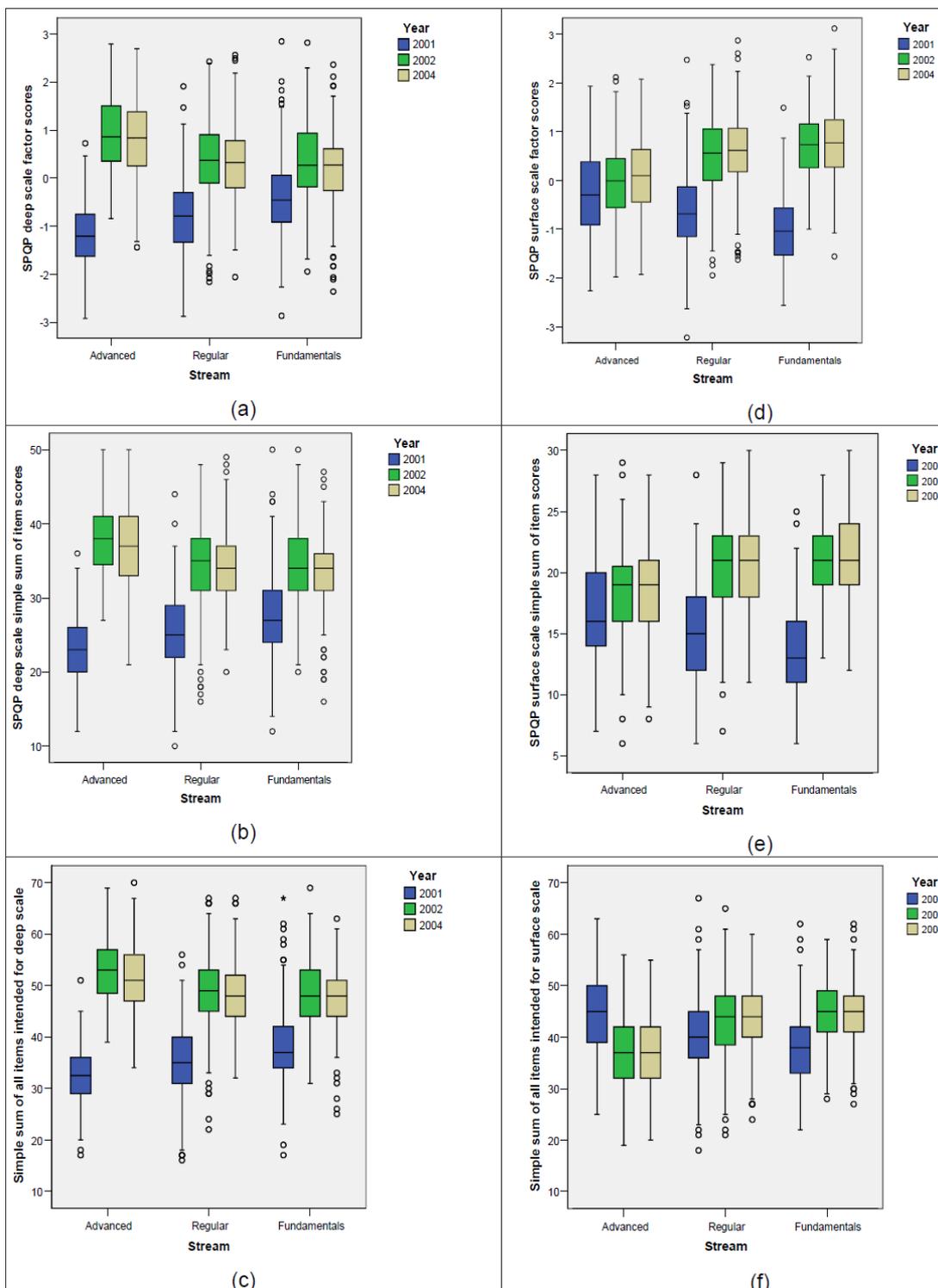
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Figure 2. *A comparison by stream and year of the deep and surface scales. The boxplots show a vertical sequence for each scale with panel (a) representing the factor scores for the SPQP deep scale and panel (d) those for the SPQP surface scale. Panel (b) represents the simple sum of item scores for the SPQP deep scale and panel (e) those for the SPQP surface scale. Panel (c) represents the simple sum of all 14 item scores that were intended to load on the deep scale and panel (f) those for the surface scale.*

implemented inventory with a sound theoretical framework, both for its development and for its practical use in a teaching environment, are evident in the

meaningful interpretations of our results summarized below.

1. The SPQ items were modified for our context based on our experiences and any changes were extensively discussed amongst a group of physics educators. Ten items were retained for the deep scale and six for the surface. The rejection of items that had anomalous factor loadings could be conceptually justified. This two-factor solution of the SPQP confirmed with the EFA and CFA and supported the factor structure of the original SPQ (Biggs, 1987).

2. The trends in reliabilities according to streams are as expected, with students with less experience in physics reporting less reliably on the deep scale and more reliably on the surface scale and vice versa. The issue of low reliabilities of the surface scale for the Advanced stream raises the question of whether Advanced students have more diverse forms of exhibiting surface approaches to learning. Moreover, the issue with the surface scale coincides with the previous studies (Biggs, 1987; Biggs et al, 2001; Wilson and Fowler, 2005).

3. Comparisons of deep factor scores, simple sums of the 10 SPQP items and all 16 items suggest that the deep scale is reliable and particularly robust, see Figure 2. The surface factor scores compare well with the simple sums of the 6 SPQP items, but not with all 16 items, suggesting that reliability and validity checks are particularly important for the surface scale. The implication is twofold: first the SPQ is robust when contextualised as shown by reliability scores; and second, the contextualisation did not alter the overall coherency of the inventory as shown by the meaningful interpretations across streams and years. This, together with the conceptual meanings associated with the items, provides confidence that the SPQP is consistent with the theoretical framework of the SPQ.

4. Changes in senior high school physics syllabus have impacted on approaches to study in the cohorts sampled in this study. The SPQP can illustrate differences between streams and years. From our study we are confident that the SPQP is a reliable and valid measure of approaches to learning physics in our context.

5. The adaptation of the SPQ into physics adds value to our project findings as it allows us to illustrate physics' specific detail between the streams. We are confident that features that could have systematically biased the findings have been minimized. Lastly the ways of thinking, learning and knowing in physics are embedded in the larger context of intentions and study methods in higher education.

Conclusion

We have adapted the Study Processes Questionnaire into physics and confirmed that a two-factor solution provides two subsets of selected items representing deep and surface approaches to learning. The resulting inventory is called the Study Processes Questionnaire for Physics, or SPQP. Further reliability and validation checks demonstrate that the two-scale SPQP is a useable inventory for our context. Reliabilities for the Advanced, Regular and Fundamentals streams are adequate and the behaviour of the mean scale scores for the three streams is not contradictory to expected student behaviours.

The process of adapting the SPQ has provided useful insights into the way physicists interpret the items, and how deep and surface approaches can be conceptualised in physics. The sound theoretical framework and research underpinning the SPQ has added value to the use of questionnaires for understanding student learning in our project. Such contextualised inventories have the potential to provide context-specific understandings of teaching and learning issues and for improving student learning.

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Appendix 1.

The two-factor solution for the modified SPQ. Odd numbered items were intended to load on the surface scale and even numbered on the deep scale. The starred odd numbered items form the surface scale and the starred even numbered items the deep scale of the Study Processes Questionnaire for Physics (SPQP). The Type of modification for each item is indicated in parenthesis.

		surface	deep
A1 (T1)	I chose **to study physics** largely with a view to the job situation when I graduate rather than out of intrinsic interest to me.		-.447
A2 (T1)	I find that at times studying **physics** gives me a feeling of deep personal satisfaction		.706*
A3 (T0)	I think browsing around is a waste of time, so I only study seriously what's given out in class or in the course outlines.		-.609
A4 (T1)	While I am studying **physics**, I often think of real life situations to which the material that I am learning would be useful.	.509	.600
A5 (T1)	I am discouraged by a poor mark on a **physics** test and worry about how I will do on the next test.	.639*	
A6 (T3)	While I realize that **ideas are always** changing as knowledge is increasing, I feel **a need** to discover **for myself what is understood about the physical world at this time.**		.715*
A7 (T1)	**When studying physics**, I learn some things by rote, going over and over them until I know them by heart.	.557*	
A8 (T1)	In reading new material **in physics** I often find that I am continually reminded of material I already know, and see the latter in a new light.		.642*
A9 (T1)	Whether I like it or not, I can see that further **study in physics** is a good way for me to get a well-paid or secure job.		
A10 (T1)	I feel that virtually any topic **in physics** can **become** interesting once I get into it.		.614*
A11 (T3)	**I am more interested in the** factual content **of physics topics** rather than theoretical **material.**		
A12 (T1)	I find that I have to do enough work on a topic **in physics** so that I can form my own point of view before I am satisfied.		.572*
A13 (T2)	I worry that, even if I have studied hard for **a physics test**, I may not get a **good mark** in it.	.604*	
A14 (T1)	I find that studying **physics** can at times be as exciting as a good novel or movie.		.467*
A15 (T0)	I generally restrict my study to what is specifically set as I think it is unnecessary to do anything extra.		-.612

A16 (T1)	I try to relate what I have learned **in physics** to that in **other subjects**.	.435	.641
A17 (T3)	**I think it is only worth studying material that I know will be examined.**		-.589
A18 (T2)	**When studying physics,** I become increasingly absorbed in my work the more I do.		.694*
A19 (T1)	I learn best **in physics when the teacher** works from carefully prepared notes and outlines major points neatly on the blackboard.	.690*	
A20 (T2)	I find most **physics** topics interesting and often spend extra time trying to obtain more information about them.		.545*
A21 (T3)	I almost resent having to **study physics**, but feel that the end results will make it worthwhile.		-.625
A22 (T3)	I believe strongly that my main aim in **studying physics is to understand it for my own satisfaction.**		.649*
A23 (T1)	I find it best to accept the statements and ideas of my **physics teachers** and question them only under special circumstances.		
A24 (T1)	I spend a lot of my free time finding out more about interesting topics which have been discussed in **my physics** classes.	-.561	
A25 (T3)	I am **prepared to work hard in my physics courses** because I feel **it will contribute to my employment prospects**.	.532*	
A26 (T3)	My studies **in physics have challenged my views about the way the world works.**		.630*
A27 (T1)	I am very aware that **teachers** know a lot more than I do, so I concentrate on what they say is important rather than rely on my own judgement.	.574*	
A28 (T0)	I try to relate new material, as I am reading it, to what I already know on that topic.	.527	.649