Measures of Student Engagement in Computer Science

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ABSTRACT
Data relating to university students' engagement is collected internationally via several large-scale student surveys such as the North American National Survey of Student Engagement. The instruments employed measure the extent to which students put their efforts into activities associated with effective learning. It is claimed that these process measures act as a reliable proxy for student attainment, and there appears to be some evidence to support this. So far, there has been little work done to investigate engagement instruments and the data they generate from a subject perspective. This paper brings together data relating to Computer Science (CS) across the range of major engagement surveys. The results of this meta-analysis appear to indicate that CS rates lower than average on many of the major engagement benchmarks and in some cases, considerably so. Particular benchmark areas giving cause for concern are identified prompting questions as to how these results should be interpreted and used in the context of a particular learning domain. We also critique aspects of the surveys themselves, suggesting that further research is needed to better understand their appropriateness for individual subjects or for groups of subjects with shared traits. The paper argues that more qualitative data is required and that other measures (such as student expectation and some subject-specific measures) are needed for a greater understanding of the CS student experience.

Categories and Subject Descriptors
K.3.2 [**Computer Science Education**]: Computer and Information Science Education

General Terms
Human Factors

Keywords
Student experience, CS, international measures

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1. INTRODUCTION
For many years universities have conducted in-house surveys to discover students' opinion of the subjects they take and of the teaching and resources provided. Such exercises gather valuable feedback often local (sometimes to individual departments or degree programs) and focused on students' experience of the teaching and learning facilities. High profile national surveys such as the UK's National Student Survey [1] have again focused on student experience in areas such as timeliness of feedback and present of teaching sessions. In 2000, a North American National Survey of Student Engagement (NSSE) was introduced [2]. The concept of engagement relates to students' activities and the amount of effort expended on "high impact" learning activities. As stated by Kuh [3]: "NSSE annually assesses the extent to which students are participating in educational practices that are strongly associated with high levels of learning and personal development". Gathering feedback on both student experience and engagement provides valuable information on students' views regarding their overall learning experience. Proponents of engagement surveys go further in claiming that engagement measurements act as a reliable predictor for student learning and that such surveys represent an easy-to-implement means of assessing the quality of educational experience provided [4].

Use of NSSE has grown in North America and Canada and a variety of research studies have been undertaken which attest to the validity of the instrument. Such studies provide evidence of a significant relationship between survey results and a variety of educational targets including developing critical thinking and moral development, and institutional outcomes such as retention and graduation rates [5,6,7]. Engagement surveys are now being used or piloted at a national level in a number of countries including Australia, China, New Zealand and the UK. For example, the Australian Government has recently introduced the University Experience Survey (UES), to "provide a nationwide architecture for collecting feedback on key facets of the higher education experience, that are measurable, linked with learning and development outcomes, and for which institutions can reasonably be assumed to have responsibility." [11].

Aggregated NSSE and UES results are widely disseminated [2, 10] and institutional data is being actively used by universities in North America to direct the development of student services [6]. It is also apparent that the uses to which this data will be put are likely to spread beyond the stated intentions of the survey creators. It is therefore important that the implications of survey data are well-understood so that it can be used to best effect for

specific groups but also to scrutinise the data collection instruments to ensure that they best capture the student experience of current students.

As yet, little work has been carried out to explore these surveys or investigate implications of engagement data for specific subject groups. Available aggregated data shows that different subjects have different mean values across the range of questions, but there is little understanding of subject profiles, of why variations occur or of what the appropriate action should be. This paper focuses on data collected from students majoring in CS. The main surveys currently in use are briefly reviewed, showing the factors assessed and the benchmarks used. Data relating to CS students is used to provide a meta-analysis of the profile for this subject group. The distinctive patterns of mean scores raise questions concerning the survey instruments and the way in which teaching and learning in CS programs is conducted.

2. CURRENT STUDENT ENGAGEMENT INSTRUMENTS

The following surveys are all used at a national level either with optional or mandatory institutional participation. NSSE is the longest-standing instrument, with other surveys developing from this to represent more tailored national instruments.

2.1 NSSE

NSSE has been delivered annually in North America and Canada for the past 15 years with the 2013 run reporting participation from 371,284 students representing 621 institutions. The survey, having 10 pages of multiple choice questions, is administered in the second half of the academic year to undergraduates of all subjects and levels of study. Questions include basic descriptive and demographic information. Engagement measures are grouped into 5 benchmarks of student behaviour evidenced by key indicators:

- Academic Challenge (17 questions) covers reflective and integrated learning; higher order learning; quantitative reasoning; and learning strategies.
- Learning with Peers (8 questions) covering collaborative learning; and discussions with diverse others.
- Experiences with Faculty (9 questions) examines student-faculty interaction; and effective teaching practices;
- Campus Environment (13 questions) covers quality of interactions; and supportive environment.

Most NSSE engagement questions use a 4 point Likert scale, with little qualitative data. Public search tools support result queries by question or according to the benchmarks. The benchmarks are assessed by different numbers of questions so a standardised measure (out of 60) is calculated for each contributing indicator, and an average for the indicators is reported. The full survey, together with access to query tools and links to supporting information can be found at the NSSE website [2].

2.2 UES

In 2011, the Australian Government commissioned a nationwide University Experience Survey (UES) [10]. The UES was originally intended for use as a means of allocating performance-based funds, but late in the development of this project, this was abandoned [13]. The UES has been in use since 2012, when it replaced the Australasian Survey of Student Engagement (AUSSE) [8] as the Australian instrument of choice. The UES was informed, in part, by the AUSSE survey (which itself has formative links with the NSSE) and as such some of the core ideas found in the NSSE are present in the UES, although it places less focus on specific academic activity to derive benchmark results. All 40 Australian universities are required to administer the survey on behalf of the Australian Government and Graduate Careers Australia (GCA).

In 2013, all 40 Australian universities administered the survey, with just over 100,000 completed surveys received. While there are significant ties to the NSSE survey, the UES identifies five different benchmarks for student engagement:

- Skills Development (8 questions) rates development of general skills such as critical thinking, ability to work with others, communication skills, and knowledge of the field.
- Learner Engagement (7 questions) covers a number of engagement areas, such as belonging to the university, participation, and interactions with other students.
- Teaching Quality (11 questions) focuses on rating overall educational experience quality, as well as expected aspects such as quality of in class experiences and feedback.
- Student Support (14 questions) relates primarily to the university services provided.
- Learning Resources (7 questions) rates a wide range of physical and virtual academic resources.

Responses are on a five-point Likert scale and are used to calculate an overall figure for each benchmark. There is also a noticeable lack of qualitative questions. Some results are made public through the Australian Government "MyUniversity" website [12], which provides a variety of information for prospective students.

2.3 SES

In the UK the Higher Education Academy began trialing a pilot student engagement survey in 2013 [9]. The pilot used a subset of 14 NSSE questions with data gathered from nine participating universities. This is referred to as the Student Engagement Survey (SES). Both the survey and number of participating institutions was extended for 2014. The pilot aims to investigate suitability and reliability of the survey in the UK context and to "support the participating institutions in using engagement data for enhancement" [9]. The NSSE-based nature of the survey allows direct comparison to the North American data. A report of the pilot gives overall outcomes [9] but detailed results are made available to participating institutions only. The expectation is that they will interpret and act on the data to enhance their teaching.

3. HOW COMPUTER SCIENCE FARES

Unfortunately, on face value, Computer Science (CS) does not fare well in the NSSE, UES or SES surveys. Although there are some differences in the method of administration and the nature of some questions, overall responses do not paint a promising picture. Note that the term Computer Science (CS) will be used to broadly represent ICT study, given the term's prevalence in North America and the UK.

3.1 NSSE

Table 1 shows data from the most recent available NSSE survey.

Table 1. Summary of NSSE 2013 benchmark indicator scores (max. 60 for each indicator, higher is better)

Subject Area	CS	Phys. Sci. (not CS)	Eng	Overall
Higher Order Learning	38	40	39	39
Reflective Learning	32	34	33	39
Learning Strategies	34	39	36	41
Quantitative Reasoning	28	38	37	29
Collaborative Learning	32	36	40	32
Discussions with Diverse Others	38	41	41	41
Student Faculty Interaction	20	28	23	24
Effective Teaching Practice	37	41	38	41
Quality of interactions	42	43	41	43
Supportive environment	31	34	32	33

As shown in Table 1, CS scores are below the overall average for all categories except Collaborative Learning on which it is equal. On several indicators, CS is only 1 or 2 points (out of 60) behind, but in Reflective Learning and Learning Strategies in particular, the gap is wider. In both those indicators, as well as Learning Strategies, Discussion with Diverse Others and Effective Teaching Practices, the Physical Sciences and Engineering are generally low-scoring and might be regarded as close subject comparisons for CS. These subject groupings are therefore included in Table 1. CS has the lowest scores in all but one indicator. Surprisingly, on the one indicator in which STEM subjects generally score well, Quantitative Reasoning, CS is a long way behind its STEM counterparts and is even slightly lower than the overall average. CS is also lower than other STEM subjects on Collaborative Learning, another aspect of STEM strength in general.

Each indicator is constructed from several questions so it is also instructive to consider how CS fares on particular questions. At this level, results are reported according to the 4-point Likert scale provided to respondents. For comparison, a score for each question is calculated by assigning a value of 0 to 3 to each answer and finding the average. A total of 34 questions form the first eight indicators listed in the table (the ninth uses a different scale and the tenth is less subject-specific). Of these 34 questions, CS is below average on all but six. In ten cases CS is 10-20% below the average, including two quantitative reasoning questions and one on interaction with staff. On no question did CS score 10% or more above average.

Challenge is explored directly by the additional key question "to what extent have your courses challenged you to do your best work?" which uses a response scale from 1 (not at all) to 7 (very much). The NSSE report refers to responses of 6 or 7 as indicating a "highly challenging" course. Only 50% of CS students rate their course as highly challenging compared to 62% of students overall (61% for Physical Sciences apart from CS, 61% for Engineering).

Another point of comparison is the difference between 1st year students and seniors. Table 2 shows benchmark data for these groups for CS compared to the general average. Overall for the general average, in all but one case (Supportive Environment) scores remain the same or increase. As students progress through their degree they generally improve with respect to the engagement benchmarks. This seems desirable as an indication of learning development. However CS results decrease for six of the ten indicators (marked by *). How to interpret this or what action needs to be taken is unclear, but it is worrying that, for example, CS students appear to spend less time engaged in reflective learning as they progress through their studies.

Table 2. NSSE 2013 benchmark indicator scores for year of study (max. 60 for each indicator).

Subject Area	CS 1st Year	CS Senior	Overall 1st Year	Overall Senior
Higher Order Learning	38	38	39	39
Reflective Learning	33	32*	36	39
Learning Strategies	36	34*	40	41
Quantitative Reasoning	28	28	26	29
Collaborative Learning	31	32	32	32
Discussions with Diverse Others	40	38*	41	41
Student Faculty Interaction	18	20	20	24
Effective Teaching Practice	40	37*	40	41
Quality of interactions	43	42*	42	43
Supportive environment	36	31*	37	33*

Similar poor results are observed in the 2010 AUSSE data. CS is ranked lowest in the categories of: Levels of Engagement, Academic Challenge, Group and Practicum Activity, General Development, Learning Outcomes and, especially disappointingly, Higher Order Thinking. AUSSE has similar questions to NSSE so, although it is no longer the primary Australian survey, it is worth noting these results alongside the NSSE data as similar concerns are raised.

3.2 UES

The UES is now the significant Australian student survey instrument and in it, fortunately, CS performs more creditably. In 2013, approximately 3200 responses were received in CS (labeled IT in the UES). The UES analysis report delivered by Graduate Careers Australia [11] breaks subject areas down into 11 broad fields (of which CS is one) and 45 specific subject areas (of which CS is only represented by one, labeled "Computing and Information Systems"). Table 3 gives a summary of UES results. Of the general categories in the UES, CS performs poorly in two: equal second lowest in Skills Development in comparison within the 45 specific subject areas; and tenth lowest in Teaching

Quality. Other categories show IT in a better light, being one above average for Learner Engagement and also Student Support, and just two below average for Learning Resources.

Table 3. UES 2013 Summary (max. 100 for each indicator).

Subject Area	Skills Dev	Learner Engage-ment	Teach. Quality	Learning Resource	Student Support
CS	72	58	74	81	54
Overall	79	57	79	83	53

As with NSSE, there is an inherent difficulty in understanding what a difference of 7 points means in the context of low Skills Development rating. Since the benchmark comprises 8 questions, more granularity is needed to understand if concerns with CS are confined to just a few elements, or if problems are widespread across the whole Skills Development area. Unfortunately access to this data is difficult, and appears limited on an institutional basis. Of the specific questions for which data has been publicly reported, two key ones relating to Teaching Quality appear problematic for CS: Quality of Educational Experience rated 75 (avg 79) and Quality of Teaching scoring 72 (avg 79). These two areas of reported concern suggest a need for further investigation.

3.3 SES

The UK pilot survey does not make data publicly available, however, the general report [9] does list some key differences between subject groups. Mathematics and Computer Science (MCS) is used as the reporting category so such results are not directly comparable to those noted above for CS alone. We might still view these as indicators of areas of interest to be investigated further. There are marked differences in response between disciplines in a number of areas. One of particular note is that only around 36% of MCS respondents reported that they had spent "very much" or "quite a bit" of time evaluating their own or others' work compared to 80% and more in some other subjects. In comparison with surveys from other countries, MCS respondents from SES notably spent more time discussing course issues and academic progress with staff, but less time talking about their career plans. In SES, students of STEM subjects reported spending significantly less time on evaluation and synthesis, but were more engaged with application of information than their counterparts from arts, humanities and social sciences.

4. ISSUES FOR COMPUTING EDUCATION

The pattern emerging for CS is a somewhat surprising one. It might be expected that, when comparing any one subject to the whole cohort, students from the subject group would display strengths in some areas and weaknesses in others. However, in NSSE in particular, CS students are below average in most indicators, and are no better than average in aspects such as quantitative reasoning where they might be expected to have an advantage. It is also surprising that, whereas students in general will improve their learning skills and their approach to studying will develop and mature, CS students show a decline in most indicators of engagement as they progress through their degree. This section highlights some of the main areas of concern.

4.1 Academic Challenge

For NSSE indicators of "Academic Challenge", CS averages 33 (out of 60) compared to the average across all subjects of 37. Further questions relating to challenge reinforce this. This is unexpected, seeming at odds with the generally acknowledged view that CS, particularly the study of programming, is difficult [15]. High levels of attrition in CS are often cited as evidence of this [16]. Why then are students assessing CS as low in questions to do with academic challenge? Why do only 50% feel that their course is highly challenging? For example, one of the contributing NSSE questions asks how much the student's work has emphasised "evaluating a point of view, decision or information source". Only 49% of CS students claim to do this "quite a bit" or "very much" compared to 73% overall. It may be that CS students are not encouraged to evaluate their work in this way or it may not be interpreted by CS students as referring to the activities they generally undertake. STEM teaching methods were observed to be particularly lacking in pedagogy to support integrative and reflective learning. Also there are indications that CS staff in the US are doing much less than non-STEM faculty to incorporate deep learning experiences into the curriculum [17]. These results are disturbing and warrant further investigation. It would also be useful to investigate the suitability of the measures across different subjects and possible differences in interpretation between students from different disciplines.

4.2 The Impact of Teaching Innovation

Many CS departments strive to develop and improve their teaching and to introduce new and innovative approaches and pedagogies to help support and engage their students. Given the poor survey results it is appropriate to question the effectiveness of the myriad teaching innovations being undertaken since they do not appear to be having a widespread impact on student engagement as measured by the NSSE across the discipline. It may be that these innovations in teaching methods are being evaluated against other measures (although it is common to see reports of interventions or new learning technologies introduced with little indication of evaluation). However, it would be interesting to regard proposed innovations from the perspective of student engagement measures and to determine their effect, particularly on measures in which CS needs to improve

4.3 Skills Development

Another key area for concern is in the acquisition of so-called "soft skills", or those that are not directly related to the CS discipline. These skills include aspects such as professional writing, presentation skills, research skills, and those that are supportive to CS professionals (and indeed all university graduates). The skills development theme of the UES has a heavy focus on such skills, and poor CS ratings may suggest that too much focus is currently placed on specific CS (and technical) skills at the expense of more generalised skills. Emphasis of soft skills in survey instruments reflects increasing awareness of their importance to all graduates. A lack of such skills will disadvantage CS graduates in the employment market. The low level of quantitative reasoning skills uncovered by NSSE is another (and rather surprising) example of low CS skills achievement.

5. IMPROVING DATA COLLECTION

The survey instruments discussed are designed to provide generic measures of student engagement and satisfaction. Given their widespread use and the public release of summarised data, they

are also considered an important mechanism to provide prospective students with an insight into specific courses and universities. The amount of information available varies, for example NSSE data for individual institutions is currently released to the institution only, whereas NSSE satisfaction scores are publicly published by institution and course [14]. Even where data is not automatically made public, some universities deem it a measure of transparency to publish their results. It seems likely that, whatever the intended purpose, pressure will increase for institutions to publish results or else it may appear they have something to hide.

NSSE developers stress that the aim of the survey is to provide individual institutions with data to inform development of their teaching, learning and support provision. In contrast, UES was initially intended as a tool for allocating performance based funds, with other functions such as public reporting regarded as secondary [13]. The Australian government later abandoned the funding link and the survey now continues to provide institutional information. However, the possibility of linking results to national funding indicates how seriously engagement surveys are taken and the acceptance at a high level that engagement measures are a valid proxy for high quality education. With surveys portraying CS in a negative light, deeper understanding is needed of the meaning of the results, and also of the instrument design and whether certain disciplines are likely to receive accurate results.

5.1 Appropriateness for CS Students

The disappointing results for CS in the various international student surveys warrant questions to be raised concerning both current teaching and the survey instruments. Each formulates different benchmarks. Also, instruments may produce differing results regardless of similarities in questions or data collection methodology. However, there are issues between the instruments and their results that highlight some key questions. One key difference between NSSE and UES is in questions relating to Higher Order Learning in NSSE and Skill Development and Teaching Quality in UES. While the UES has questions of a general nature that are applicable to all disciplines, NSSE asks specifically: "During the current school year, about how many papers, reports or other writing tasks of the following length have you been assigned", with students asked to rate for tasks up to 5 pages, between 6-10 pages, and 11 pages or more. For CS this question poses two potential difficulties. Firstly, the nature of CS study (relative to many other disciplines) does not lend itself to so many lengthy writing challenges so responses from CS students are destined to be much lower than many other areas of study. Secondly, for students who extrapolate the question to relate to coding exercises, design specifications, or other CS related tasks, responses would vary wildly, rendering this question unreliable.

The UES is not without its concerns in this area but in the area of Skill Development only two of the eight contributing questions relate to discipline specific knowledge, whereas the remaining six ask students about the extent to which their course has developed general skills. In the UES, these are more general academic abilities that there would be a reasonable expectation that all university students would develop. This may be one of the reasons for better CS achievement in the UES compared to NSSE.

Overall, the suitability of the survey instruments to accurately capture levels of academic engagement in the CS context should be examined. While there is no question that many of the skills examined in both NSSE and UES are those considered to be key graduate attributes of any discipline, there needs to be a better understanding of how engagement is evidenced within specific disciplines. It should not be biased towards some disciplines nor should it focus on factors crucial to a particular discipline.

5.2 Reliability of Results

Concerns have been raised over the reliability of self-reporting and the interpretation of questions that are presented in a relative form. For example, some NSSE questions ask whether students perform a certain activity "very often", "often" and so on. These scales may be interpreted in a variety of ways. Terms used in the survey may also give rise to a variety of interpretations. The approach relies on students self-reporting and questions are not repeated in different ways. This has led to claims that such surveys lack the basic requirements for validity and reliability [18]. This has been met with robust response from survey proponents [19] however, although various studies have been conducted to refute the suggested deficiencies, very little work has been done to establish the appropriateness and validity of the instruments across different subjects or to explore the possibility of different interpretations of questions by different groups of students.

A further concern is the significance of points of difference, for example, how should we regard a 32 in relation to a 34? As benchmarks, the figures can be taken by institutions to map their own progress by longitudinal study of successive surveys and to identify areas to be enhanced to improve aspects significant for the particular context. However, this inevitably involves questions about sector comparability in order to make decisions on interventions. Since many interventions occur at a subject or faculty level, it also requires an understanding of what the indicators mean and what should be targeted at a subject level.

Given the importance of the results of such international surveys both for understanding our students and for public perception, it is important to understand the extent to which CS courses are falling short (and in what ways) or if in some cases there might be more appropriate measures of student experience.

5.3 Understanding the Issues Raised

In order to utilise the survey results effectively at a departmental level, it is important to understand what they really represent and how best they are to be used to suggest effective interventions. The SES report notes, "there were marked differences between disciplines, likely to be due to different pedagogies and expectations." [9]. However, there has been no work to confirm the reasons or to establish the implications of such differences. Nelson Laird et al [20] provide a statistical analysis to show the relationship of discipline traits (such as hard/soft, pure/applied) to engagement scores but this provides little interpretation or guidance to direct practice. Further, differences within the groups of subjects sharing traits are not explored and hence it does not provide explanation for a pattern of results within a single subject, which differs from the norm for subjects with shared traits.

Ultimately, while the surveys discussed highlight poor engagement levels, they do little to provide insight into meaningful reasons for disappointing results. Reporting is mainly focused on quantitative representations of academic engagement. Consequently there is no explanation of the way CS students report their engagement with general skills development, reflective learning, learning strategy and the like. Inclusion of more qualitative questions would enable educators to understand more deeply the issues at hand and institute programs to address them. Similarly, questions that more broadly encompass the total

university experience could paint a more balanced picture of "experience". The surveys discussed arose from a desire to quantify student experience for comparison between disciplines, institutions, and for ease of reporting. However if such huge effort is being undertaken to obtain insight for students across North America, Europe, and Australia, then the opportunity should be taken to obtain a richer and more complete understanding of student experience.

6. Further Work

This paper has considered widely used student engagement instruments and noted the consistently low scores recorded for CS students. Areas exhibiting a particularly large gap include level of academic challenge, reflective and integrative learning, learning strategies and effective teaching practices. Levels of transferable skills also appear to be low for CS students. These all need further investigation to understand the meaning, implications and appropriate action to be taken (if any). For example, it is unlikely that CS degrees should be altered to include multiple assessments involving extended essays simply because this is an "engagement measure". Other measures for CS may be more appropriate. However, if writing skills are genuinely lacking then appropriate ways to address the problem in the CS curriculum are needed. There is also a need to study further the surprising and worryingly low score relating to quantitative reasoning.

Student engagement surveys provide just one source of information about students' experience, activity and learning. To understand areas of low performance it is necessary to bring together different perspectives. Beaubouf & Mason [16] point to a number of factors in CS attrition, including misconceptions about what CS involves, poor information and advice when choosing CS, poor teaching, lack of feedback and lack of study skills. Some of this (for example, poor study skills) reinforces the survey findings. However, other aspects of CS student experience need to be examined further to see what our students think and why their survey responses are as they are. The issue of expectation and of how students' views change over their first year is of particular interest here and further work is planned to gain a better insight.

There is also a need for further work to deal with the data now available, to determine statistical significance of results and to compare additional data from other countries with different approaches. As noted by the UES 2011 Development Report [13]: "the availability of a student ID number provides incredible potential for tracking students over time and … requires an 'information model' to be established to support statistical analysis" (p.67). The divergence of different national instruments intended for similar purposes raises the question of how (and if) results can be compared internationally.

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