Houston, we have a problem:
There’s a leak in the CS1 affective oxygen tank
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ABSTRACT
The affective domain can be used to support the internalization of cognitive content and foster the development of curriculum and industry-related interests, attitudes, values, and practices. This study investigated correlations between affective factors and course grade. Interest, perceived competence, effort, lack of pressure, and value correlated significantly with CS1 course grades. Moreover, this study investigated the levels of these factors over the course of CS1. Almost all of the levels of these significant factors decreased significantly during the CS1 course as measured by pretests and posttests. Results of this study further indicated that the use of specific affective objectives and instructional strategies lessened these decreases.

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

General Terms
Design, Experimentation, Management, Measurement

Keywords
Affective objectives, affective assessment, interest, competence, effort, pressure, value, belonging, motivation, Intrinsic Motivation Inventory, Institutional Integration scale, student achievement, retention, CS1, CS education research

1. INTRODUCTION
Elements of the affective domain include interests, attitudes, and values. These affective elements support the internalization of cognitive content. Like Bloom’s cognitive domain [4], Krathwohl’s affective domain consists of levels of achievement. These levels are: 1.0 receiving, 2.0 responding, 3.0 valuing, 4.0 organization, and 5.0 characterization [13]. Each level represents a higher level of learner internalization. Professional organizations such as the National Association of Colleges and Employers (NACE) have identified characteristics needed in college graduates. Many of these characteristics are affective. NACE’s top ten list is: communication skills (verbal and written), honesty/integrity, teamwork skills, interpersonal skills, motivation/initiative, strong work ethic, analytical skills, flexibility/adaptability, computer skills, and self-confidence [1].

The effects of student affect extend in and beyond the classroom. The cognitive and affective domains are interrelated. There is no clear division between these two educational domains; growth in one domain tends to contribute to growth in the other [13, 15]. Low levels of interest, relevance, and the sense of belonging, are among the top reasons for early departure (i.e. first year) from colleges and universities [11, 14, 17, 18, 20]. Student persistence is particularly important in the SMET (Science, Mathematics, Engineering, and Technology) disciplines which are experiencing shortages in college graduates especially in underrepresented groups [11, 19]. These disciplines are not only losing low-achieving students but also considerable numbers of high quality, talented students [11, 14]. Moreover, even when students do persist and become employed, many have not internalized needed professional practices and skills [6, 7, 12].

In order to determine whether students possess NACE characteristics and value professional practices, affective assessment must be conducted. In this context, affective assessment can contribute to fuller understanding of course outcomes, can lead to the improvement of courses, and can assist in the fulfillment of accreditation mandates from organizations such as ABET-CAC. The American Association for Higher Education (AAHE) supports this attention to affective assessment in it’s Nine Principles of Good Practice for Assessing Student Learning where the point is made that learning “involves not only knowledge and abilities but values, attitudes, and habits of mind that affect both academic success and performance beyond the classroom” [2].

In CIS disciplines, it is generally reported that course-completion rates in CS1 are low. Often CS1 is viewed as a “weed-out” course. CIS classrooms are characterized by a “defensive climate” [3] not conducive to student achievement. Studies also indicate that high quality students are also leaving [11, 14, 17, 18, 20]. These studies are by and large qualitative in nature. In our study, we have sought to provide quantitative confirmation of these findings.
Our results indicate that interest, perceived competence, effort, pressure, and value are significantly correlated with course grade in CS1. Furthermore, using pretests and posttests, our results show significant drops in these affective factors during the semester in students who completed the course. In other words, there is a significant leak in the CS1 affective oxygen tank. Houston, we have a problem.

2. PRIOR WORK

In 1994, our school established a Bloom-based cognitive framework [10]. This work generated materials which were transferable to other instructors and ensured that a common set of objectives were being met. Students reported that they perceived this approach to be beneficial. Yet despite continuing efforts, course-completion rates usually remained in the 30 to 50% range.

During 2001, two CS1 instructors, the authors, began to address these low course-completion rates by enhancing CS1’s cognitive framework with two affective initiatives [8]: (1) the discussion approach, and (2) the self-reflection approach. The discussion approach involved the students’ in-class discussions about the students’ cognitive-affective potential. The self-reflection approach used a tool called the BAM chart (Bloom-Affective Maslow) which was designed to promote self-regulated learning. When piloted these efforts resulted in significantly higher course-completion rates. However, without clearly defined affective objectives, the goals of these initiatives were unclear and difficult to assess. Moreover, these initiatives did not transfer to other instructors who were uncomfortable with our methodologies.

In 2002, the authors introduced specific affective objectives to the CS1 course. We conducted affective assessment using validated instruments to determine which affective factors contributed to higher achievement as measured through course-completion rates and grades. This effort [9] identified perceived competence, effort, and interest/enjoyment as factors which were significantly correlated with course grade. Student belonging with peers (i.e. student-peer belonging), student belonging with faculty (i.e. student-faculty belonging), and lack of pressure were found to be significantly correlated with grade factors for specific ethnic groups.

3. METHODOLOGY

The goals of our study were threefold: (1) to further identify specific affective factors which promote student achievement as measured by course grade, (2) to determine significant differences in the levels of these factors at the beginning and end of CS1, and (3) to identify any significant differences between the affective levels at the end of the semester between CS1 sections using our affective instructional methodology and those sections which did not use a specific affective methodology. To accomplish these goals, we administered pretests and posttests versions of the Intrinsic Motivation Inventory (IMI) [16] and pretests and posttests versions of the Institutional Integration scale [17] to all CS1 sections during Spring 2003. There were four course sections and three instructors. Each instructor had an individual teaching style but the same cognitive content was covered in each section in a synchronous manner.

3.1 Assessment Instruments

The Intrinsic Motivation Inventory (IMI) is a validated instrument which has been used in studies for measuring intrinsic motivation, internalization, and self-regulation. The scales we used measured interest-enjoyment, perceived competence, effort, value-usefulness, and felt pressure-tension regarding a particular activity. Students rated items based on a seven-point scale ranging from not at all true to somewhat true to very true. The IMI was designed to be tailorable to the specific activity which is being measured [16] and our IMI instrument was tailored for CS1. Figure 1 shows sample questions from this IMI.

<table>
<thead>
<tr>
<th>Sample Questions from IMI Pretest</th>
</tr>
</thead>
<tbody>
<tr>
<td>I think problem-solving strategies are important skills.</td>
</tr>
<tr>
<td>I think I will enjoy writing programs for business applications.</td>
</tr>
<tr>
<td>I think I will be pretty good at programming.</td>
</tr>
</tbody>
</table>

The Institutional Integration scale is a validated instrument designed to measure the degree of peer-group interaction and student-faculty interaction. A Likert-scale was used: strongly disagree, disagree, don’t know, agree, and strongly agree. These factors were used to measure the students’ sense of belonging with other students and faculty. Samples of Institutional Integration questions for CIS are shown in Figure 2.

<table>
<thead>
<tr>
<th>Sample Questions from Institutional Integration Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>It has been difficult for me to meet and make friends with other students in CIS.</td>
</tr>
<tr>
<td>My non-classroom interactions with at least one member of the CIS faculty has had a positive influence on my career goals and aspirations.</td>
</tr>
<tr>
<td>My interpersonal relationships with other students in CIS have had a positive influence on my personal growth, attitudes, and values.</td>
</tr>
<tr>
<td>My non-classroom interactions with at least one member of the CIS faculty has had a positive influence on my intellectual growth and interest in ideas.</td>
</tr>
</tbody>
</table>

3.2 Affective Instructional Methodology

Although the specific instructional methodology used in the sections using affective objectives is not the focus of this paper, we present a brief description of that methodology here. Two of the four sections in this study used affective objectives (see Figure 3 for examples). These sections were characterized by active and cooperative learning activities. Team work was emphasized. These sections implemented the discussion approach and self-
reflection approach described in the prior work [8, 9]. The laptop policy of our School of CIS (i.e. students must bring personal laptops to each CS1 class) provided classroom opportunities for hands-on programming activities during class times. The active and cooperative components of the course facilitated affective assessment. Course adjustments to enhance student achievement are made based upon in-class affective assessments, cognitive assessment, and student feedback.

1.0 Receiving
Students become aware that testing is a part of the software development life cycle during the initial programming labs.

2.0 Responding
Students use coding standards as taught in the lectures with minimal prompting in the lab.

3.0 Valuing
Students consistently show strong work ethic, cooperation, and initiative while working in groups.

4.0 Organization
Students discuss a wide variety of useful personal initiatives indicative of a growing commitment to life-long learning.

4. RESULTS
Several analyses were conducted on the pretest and posttest scores and course grades to investigate correlations between affective factors and grade. First, the pretests and posttests scores for each factor were correlated with the course grade. Second, paired-samples t tests were conducted to determine whether there were significant differences between the pretest and posttest scores for each affective factor. Third, independent-samples t tests were conducted to determine if there were any significant differences in the posttest affective factors between the two sections using affective objectives and the two sections not using affective objectives.

4.1 Course grade and affective factors
Significant correlations between course grades and the affective factors measured in the pretest and posttest for all students in the sample are shown in Table 1. All IMI posttest factors showed a significant correlation with course grade. The only pretest factor to correlate significantly with course grade was perceived value. The affective factors measured in the Institutional Integration scale, student-peer belonging and student-faculty belonging, did not indicate any significant correlations.

4.2 Comparison of pretests and posttests
All IMI affective factors showed negative, significant shifts from pretest to posttest in the paired samples t tests. These significant differences between pretest scores and posttest scores for all students in the sample demonstrate the affective leak in CS1 at our university. The results of these t tests are shown in Table 2. The student-faculty belonging factor, from the Institutional Integration scale, also dropped but the decrease was not statistically significant. The student-peer belonging factor was the lone factor which showed an improvement. This factor is largely under the students’ control and is supported by our university’s Supplemental Instruction program, the student ACM chapter, and departmental activities. This improvement was statistically significant.

Table 1: Correlations of Factors with Course Grade

<table>
<thead>
<tr>
<th>Factors</th>
<th>Pearson Correlations</th>
<th>N</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest Value</td>
<td>0.215*</td>
<td>86</td>
<td>0.047</td>
</tr>
<tr>
<td>Posttest Interest</td>
<td>0.640**</td>
<td>56</td>
<td>0.000</td>
</tr>
<tr>
<td>Posttest Competence</td>
<td>0.588*</td>
<td>56</td>
<td>0.001</td>
</tr>
<tr>
<td>Posttest Effort</td>
<td>0.445**</td>
<td>56</td>
<td>0.001</td>
</tr>
<tr>
<td>Posttest Lack of Pressure</td>
<td>0.614**</td>
<td>56</td>
<td>0.004</td>
</tr>
<tr>
<td>Posttest Value</td>
<td>0.614</td>
<td>56</td>
<td>0.000</td>
</tr>
</tbody>
</table>

** Significant at the 0.01 level (two-tailed)
* Significant at the 0.05 level (two-tailed)

Table 2: Pretest/Posttest Paired-Samples Comparisons

<table>
<thead>
<tr>
<th>Pretest/Posttest Factors</th>
<th>t-value</th>
<th>Degrees of Freedom</th>
<th>Significance (two-tailed p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest</td>
<td>-2.811**</td>
<td>52</td>
<td>0.007</td>
</tr>
<tr>
<td>Competence</td>
<td>-4.106**</td>
<td>52</td>
<td>0.000</td>
</tr>
<tr>
<td>Effort</td>
<td>-3.706**</td>
<td>52</td>
<td>0.001</td>
</tr>
<tr>
<td>Lack of Pressure</td>
<td>-2.721**</td>
<td>52</td>
<td>0.009</td>
</tr>
<tr>
<td>Value</td>
<td>-4.124**</td>
<td>52</td>
<td>0.000</td>
</tr>
<tr>
<td>Faculty Belonging</td>
<td>-1.004</td>
<td>52</td>
<td>0.320</td>
</tr>
<tr>
<td>Peer Belonging</td>
<td>4.592**</td>
<td>52</td>
<td>0.000</td>
</tr>
</tbody>
</table>

** Significant at the 0.01 level (two-tailed)
* Significant at the 0.05 level (two-tailed)

4.3 Lessening the leak
The sections using specific affective objectives showed higher posttest scores for each affective factor when compared with sections not using affective objectives. These differences are shown in Figure 4. To investigate these differences, we conducted an independent-samples t test to see if any of these individual differences were significant. The sections using our affective methodology showed significantly higher posttest scores for effort, t(51) = 6.099, p = .017, and student-peer belonging t(51) = 4.377, p = .041.

It is important to note that all sections showed a decrease in all factors except student-peer belonging from the beginning to the end of the semester. Figure 5 shows these decreases averaged across sections.
significant. Additionally, results indicated that the use of specific affective objectives and affective instructional strategies lessened these decreases. Some of these lessening effects were significant.

Affective objectives, like cognitive objectives, provide specific disciplined-based goals which can be used to support and measure student achievement. These affective goals, like their cognitive counterparts, can be pursued by different instructors using their own instructional strategies. This is a salient advantage of objectives-based education. Anticipated benefits of a broader implementation of this integrated cognitive-affective approach are higher cognitive achievement, higher course-completion rates, higher retention rates, more diverse student representation, higher student enthusiasm, and more complete fulfillment of industry demands for qualified and motivated CIS professionals.

7. ACKNOWLEDGMENTS
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8. REFERENCES


