Perceived Instrumentality and Career Aspirations in CS1 Courses: Change and Relationships with Achievement

Markeya S. Peteranetz

Abraham E. Flanigan

Duane F. Shell

University of Nebraska-Lincoln

114 Teachers College Hall

Lincoln, Nebraska 68588

1-402-472-8331

markeya.dubbs@huskers.unl.edu,

abrahamflanigan@gmail.com,

dshell2@unl.edu

Leen-Kiat Soh

University of Nebraska-Lincoln

122E Avery Hall

Lincoln, Nebraska 68588

1-402-472-6738

lksoh@cse.unl.edu

ABSTRACT

We explored CS1 students' perceived instrumentality (PI) for the course and aspirations for a career related to CS. Perceived instrumentality refers to the connection one sees between a current activity and a future goal. There are two types of PI: endogenous and exogenous. Endogenous instrumentality refers to the perception that mastering new information or skills is important for achieving distal goals. Exogenous instrumentality refers to the perception that obtaining an external reward (such as a grade) is essential for obtaining future goals. We investigated (1) how students' PI and career aspirations changed over the course of a semester, (2) how these changes differed as a function of course enrollment and major (CS or not), (3) the relationship between PI and career aspirations, and (4) whether PI and career aspirations predicted academic achievement. Overall and for most subgroups, exogenous instrumentality increased significantly and endogenous instrumentality decreased significantly across the semester, though the degree of change varied among some subgroups. Career aspirations decreased overall and for most subgroups, but CS majors showed a much smaller decrease than non-majors, and students in a CS/business honors course showed an overall increase in career aspirations. Finally, students' achievement outcomes were predicted by their PI and career aspirations. These findings contribute to the literature on motivation in CS1 courses and points to PI as a promising avenue for influencing student motivation. Implications for student motivation and retention in CS and other STEM courses are also discussed.

Categories and Subject Descriptors

K.3.2. [Computers and Education]: Computer and Information Science Education

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General Terms

Performance, Human factors, Theory

Keywords

Perceived instrumentality; Career aspirations; CS1

1. INTRODUCTION

In today's rapidly advancing technological environment, the need to attract and retain students in STEM majors is possibly greater than ever before [22, 31]. It has been proposed that career opportunities in STEM-related fields will grow at nearly twice the rate as opportunities in non-STEM fields between 2008 and 2018 [22]. The need for more post-secondary students to major and graduate in STEM fields, especially computer science (CS), is widely recognized, [3, 22] and there is increasing recognition of the need for computational thinking both for CS and across the broader spectrum of STEM and non-STEM disciplines [29].

To address these needs, considerable effort has been focused on attracting and retaining students in CS. These include efforts to engage and motivate non-CS majors [5]; instructional strategies such as pair programming, peer-based instruction, and media computation [21]; using personal robots [16]; project-based instruction with different tracks [10]; and framing an appropriate classroom climate to reduce student anxiety about their status among peers and encourage them to co-learn and speak up in class [2]. But, despite these efforts, enrollment and persistence in CS continues to be problematic, with enrollments actually declining over the past decade [18].

This lack of progress indicates a need to better understand the motivations of students who are taking CS courses and how their motivation is contributing to their success and retention. Many aspects of student motivation in CS courses have been examined including goal orientation [7], mindsets [4], and self-efficacy [25], and these motivators influence both student engagement and achievement. The purpose of this study was to investigate two relatively understudied motivators in CS courses: perceived instrumentality (PI) and career aspirations. PI and career aspirations differ from previously studied motivators because they reflect motivation related to distal outcomes such as career success rather than proximal outcomes such as course achievement. As a result, PI and career aspirations provide a different perspective on student motivation.

We examined PI [6, 11, 12, 17], and specifically considered (a) how PI changes over the semester in introductory CS1 courses and (b) how that change potentially affects students learning and achievement. Although prior studies have found that PI is associated with student achievement in undergraduate CS1 courses, results have differed depending on whether PI was assessed at the beginning [27] or the end [24] of the course, with findings not always corresponding to expectations based on PI theory [6, 12]. These different findings from the beginning and end of the semester assessments suggest that important changes in students' PI occur during the semester. Our study is designed to examine these possible changes and the impact of those changes on student achievement to help resolve these conflicting prior findings.

The second motivator we investigated is future career aspiration. Prior studies in engineering have found that the extent to which students aspire to a career in engineering influences their achievement, engagement, and persistence [1, 8]. Specifically, future career aspirations have been found to be associated with how much students perceive a specific course as instrumental to their future [8]. No studies of career aspirations have been done in CS, however. Our study is designed to fill this gap by examining change in students' future aspirations for using CS and computational thinking in their career across the semester in CS1 classes and examining how changes in career aspirations are associated with PI.

2. THEORETICAL FRAMEWORK

2.1 Perceived Instrumentality

Perceived instrumentality refers to a task-specific evaluation of how a current learning activity connects to future goals [11, 12, 14, 28]. Prior research has found that motivation and achievement are enhanced when students see a connection between present tasks and their future goals [6, 13, 14, 28].

Researchers have proposed two types of instrumentality: endogenous and exogenous instrumentality. Endogenous instrumentality is the perception that mastering new information or skills is important for achieving personally meaningful distal goals [12]. An example of endogenous instrumentality is an aspiring software engineering trying to master the concepts taught in her introductory programming course because she sees them as essential for success in her future career in software engineering. Exogenous instrumentality refers to the perception that there is only a utilitarian connection between the attained outcome of a course or activity (such as the grade) and achievement of future goals [12]. A CS major may be motivated to earn an A in their biology course because they see a need for a high GPA for future graduate school or employment; but, have no personal interest in learning biology for personal growth. Theoretical formulations of PI [12, 14, 28] generally hold that endogenous PI is the more powerful positive motivator because instrumentality for learning course material for personal growth is a source of intrinsic motivation. While the utility-based motivation from exogenous PI can be positively motivating, this motivation is based on an extrinsic/external reward, and an extrinsic reward alone can be a poor motivator.

In one study examining students in CS1 courses, students' PI for the course at the end of the semester was found to be associated with higher student grades and learning [24]. Endogenous PI was associated with higher grades and learning; exogenous PI was associated with lower grades and learning. A similar pattern was found for engagement and self-directed learning. These findings were consistent with theoretical formulations of PI [12, 14, 28]

that propose that endogenous PI is a more powerful positive motivator and provide evidence that exogenous PI may be problematic. Similar findings were obtained from studies examining student profiles of motivated, self-regulation and engagement in CS1 courses [19, 26]. Students in adaptive profiles (strategic, knowledge building) associated with high achievement were much higher in endogenous PI than students in more dysfunctional profiles (apathetic, surface learning, learned helplessness) associated with lower achievement. Students in dysfunctional profiles also typically had higher exogenous than endogenous PI.

Contrary findings, however, emerged in a study of students' entering course motivation in CS1 courses and their grades and retention [27]. Consistent with prior findings and theory, higher exogenous PI at the start of the semester was negatively associated with final course grades; however, contrary to expectations from prior studies, higher endogenous PI at the start of the semester was also negatively associated with final course grades. The only exception was for an honors course where entering endogenous PI was positively associated with final grades.

In this paper, we addressed these contradictory findings concerning students' entering and end-of-course PI by examining how their endogenous and exogenous PI changed across the semester and whether this change differed for students in CS1 courses tailored for different student populations.

2.2 Career Aspirations

Research has found that students who make a connection between academic courses and activities and their potential future selves experience increased motivation towards current tasks and higher levels of academic achievement [6, 14, 15]. Students are more motivated for a CS course if they can envision themselves in a CS-related job and aspire to pursue that job. Research in engineering has found that students who maintained high future career aspirations tended to view their engineering coursework more favorably than their peers but that students had changes in these aspirations over time [1]. Also, aspirations related to a future career in engineering have been related to higher perceptions of endogenous instrumentality for engineering coursework [8].

These studies suggest important links between career aspirations and PI for courses, especially endogenous PI. These links have not been extensively examined, and importantly, have not been examined at all in CS. Our current study sought to address this lack of research by examining changes in career aspirations across the semester in introductory CS1 courses along with how changes in aspirations might be related to changes in endogenous and exogenous PI.

3. THE PRESENT STUDY

The purpose of this study was to investigate how PI and career aspirations of undergraduates in a suite of CS1 courses changed across the semester. Moreover, we explored how these changes were associated with students' learning outcomes. The central research question guiding this study was: *How dynamic are undergraduate computer science students' PI and career aspirations in CS1 courses?* The following specific research questions were examined:

1. How do students' endogenous and exogenous PI in CS1 courses and their career aspirations change from the beginning to the end of the semester?
2. Do changes in students' PI and career aspirations across the semester differ as a function of course enrollment or major?

3. What is the relationship between undergraduate students' career aspirations and their endogenous and exogenous PI for a CS1 course?
4. How do changes in PI and career aspirations across the semester relate to students' CS1 learning outcomes?

4. METHODS

4.1 Participants

Participants in this study were 621 undergraduates (538 males; 83 females) from a suite of CS1 courses at a large Midwestern university. Participants included 297 freshmen, 184 sophomores, 72 juniors, 51 seniors, and 17 who identified as "other." Of these participants, 447 (383 males; 64 females) provided complete data and were included in the analysis. Participants were recruited from a suite of CS1 courses that catered to different undergraduate student populations. Specifically, the suite consisted of separate courses tailored for: CS majors ($n = 72$), engineering majors ($n = 205$), a combination of computer, engineering, and physical science majors ($n = 108$), humanities majors ($n = 6$), and interdisciplinary business/CS honors students ($n = 56$). Core content was the same for all courses, but courses were tailored for the different majors with different programming languages, lab exercises, and programming assignments. The study was approved by the University Institutional Review Board (IRB#: 20120111818EP).

4.2 Instruments

4.2.1 Perceived Instrumentality (PI)

PI was measured using the Perceptions of Instrumentality Scale [11, 19, 26]. *Endogenous PI* (4 items) assesses the perceived instrumentality of learning the course content for obtaining distal goals (e.g., "What I gain from this class will shape my future."). *Exogenous PI* (4 items) assesses the utility of attaining course grades for achieving distal goals (e.g., "The only thing useful to me in this class is the grade I get."). Students indicated their agreement with each question using a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Endogenous and exogenous PI scale scores were computed as the mean of the items in each scale. Cronbach's alpha reliability estimates for the endogenous and exogenous PI scales were .92 and .93 respectively.

4.2.2 Career Aspirations

Career aspirations were assessed with an instrument based on the Project for the Analysis of Learning and Achievement in Mathematics (PALMA) [20]. The original scales were for high school math students and were rephrased for post-secondary CS by the researchers. Participants responded to three items assessing aspirations to use CS concepts and skills in their future career (e.g., "In whatever career I choose, I would like to work in a job that uses computer science applications, programming, or computational thinking."; "In my career, I would like to work with projects that involve a lot of computer science applications, programming, or computational thinking.") at both the beginning and end of the semester. Participants indicated their agreement to each item using a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). The career aspirations score was computed as the mean of the three scale items. Cronbach's alpha reliability estimate for the scale was .95.

4.2.3 Course Achievement Measures

To investigate how changes in PI and career aspirations predict students' academic outcomes, final course grades and perfor-

mance on a computational thinking knowledge test were used as the barometers of achievement.

4.2.3.1 Course Grades

While completing the informed consent sheet, participants granted the researchers permission to obtain access to their final course grades. Course grades were obtained from the instructor's final grade roster for each course. The grading is on a 13-point scale from F (0.0) to A/A+ (both 4.0). Because raw grades are not directly comparable across courses, grades were z-score standardized within each course prior to analysis.

4.2.3.2 Computational Thinking Knowledge Test

All courses in the suite of introductory CS courses from which participants were recruited include the same basic core of computer science topics. To create a common measure of retention of these core topics that could be used across all of the courses, a Web-based, 13-item test of computational thinking and CS knowledge containing a blend of conceptual and problem-solving questions was developed by computer science and engineering faculty. The test addresses common core content including selection, looping, arrays, functions, algorithms, search, and sorting. Information on the test development can be found in [19, 26]. The Cronbach's alpha estimate for the knowledge test was .73.

4.3 Procedures

This study took place as part of a larger NSF-funded study focused on improving students' abilities to learn computational thinking by incorporating computational and creative thinking exercises into undergraduate CS courses, including CS1 courses. Participants in the study CS1 classes completed the Perceptions of Instrumentality Scale and career aspirations items during lab or lecture sessions during the first week of the semester. During the last two weeks of the semester, participants repeated the beginning-of-semester instruments and completed the Computational Thinking Knowledge Test in lab or lecture sessions. All of the surveys were completed using the Survey Monkey® online survey tool. After the semester ended, students' final course grades were obtained from the instructors' final grade rosters for each course.

4.4 Analysis Procedures

All data analysis was performed using SPSS v. 21 and 22. Multivariate analysis of variance (MANOVA) and univariate analysis of variance (ANOVA) were done using the General Linear Model repeated measures procedure and the One-way ANOVA procedure. Linear regression analyses were conducted using the Linear Regression procedure.

5. RESULTS

The present study explored (a) whether CS1 students' endogenous and exogenous PI and career aspirations changed across the course of the semester, (b) the possibility of course enrollment and major as moderators of change in PI and career aspirations, (c) the relationship between PI and career aspirations, and (d) how changes in PI and career aspirations could be used to predict course achievement, as measured by standardized course grades and computational thinking knowledge test scores. Changes in sample sizes reflect changes in the number of participants who provided relevant data at each time point. Note that in this section we present the analyses and results. In Section 6, we summarize the findings with implications for CS education.

5.1 How do students' endogenous and exogenous PI of CS1 courses and their career aspirations change from the beginning to the end of the semester?

To determine whether participants' endogenous and exogenous PI changed from the beginning to the end of the semester, a repeated-measures MANOVA was conducted. Overall for all participants, PI changed significantly from the beginning of the semester until the end (Wilks' $\lambda = .751$, $F(2, 441) = 73.163$, $p < .001$, partial $\eta^2 = .249$). Univariate follow-up tests revealed that there was a significant change for both endogenous ($F(1, 442) = 139.059$, $p < .001$, partial $\eta^2 = .239$) and exogenous ($F(1, 442) = 71.578$, $p < .001$, partial $\eta^2 = .139$) instrumentality. Endogenous instrumentality scores decreased across the semester from a mean of 3.91 at the beginning of the semester to 3.47 at the end. Exogenous instrumentality scores increased across the semester from a mean of 2.19 at the beginning of the semester to 2.57 at the end. These findings indicate that *students' perceived instrumentality for learning the course material in their CS1 course was decreasing while their instrumentality for the utility of grades was increasing*.

To determine whether participants' career aspirations changed from the beginning to the end of the semester, a repeated-measures ANOVA was conducted. Overall for all participants, career aspirations changed significantly from the beginning of the semester until the end (Wilks' $\lambda = .961$, $F(1, 440) = 18.073$, $p < .001$, partial $\eta^2 = .039$): career aspirations decreased from a mean of 3.43 at the beginning of the semester to 3.25 at the end. This finding suggests that *introductory CS1 students' aspirations to pursue a career that utilized a substantial amount of computer science applications and computational thinking declined during the semester of taking their CS1 course*.

5.2 Do changes in students' PI and career aspirations across the semester differ as a function of course enrollment or major?

Course enrollment and major were examined as possible moderators of the changes in PI and career aspirations. Other important possible moderators (viz., gender) are not reported because the limited number of individuals in some subgroups reduced statistical power and led to difficulty in interpreting results.

5.2.1 Course Enrollment

The CS1 humanities course was not included in any between-class analyses because of the low number of participants in that course ($n = 6$). Mixed MANOVA was used to test whether changes in students' PI differed as a function of course enrollment. Group means for endogenous and exogenous instrumentality at the beginning and end of the semester are shown in Table 1. The main effect of time was significant (Wilks' $\lambda = .842$, $F(2, 432) = 40.608$, $p < .001$, partial $\eta^2 = .158$) as was the main effect of course enrollment (Wilks' $\lambda = .746$, $F(6, 864) = 22.733$, $p < .001$, partial $\eta^2 = .136$). The interaction between course enrollment and change in PI was also significant (Wilks' $\lambda = .945$, $F(6, 864) = 22.733$, $p < .001$, partial $\eta^2 = .028$), indicating that change in PI across the semester was different in different courses. Univariate follow-up analyses revealed that both main effects and the interaction effect were significant for both endogenous and exogenous instrumentality (results summarized in Table 2). As shown in Table 1, *all courses except for the Business/CS Honors course showed substantial shifts in both endogenous and exogenous instrumentality* (Cohen's D s from ± 0.24 to 0.68). Significant pairwise comparisons between courses are also shown in Table 1.

Mixed ANOVA was used to test whether changes in students' career aspirations differed as a function of course enrollment. Group means for career aspirations at the beginning and end of the semester are shown in Table 1. The main effect of time was significant (Wilks' $\lambda = .987$, $F(1, 437) = 5.840$, $p < .05$, partial $\eta^2 = .013$), as was the main effect of course ($F(3, 437) = 53.808$, $p < .001$, partial $\eta^2 = .270$), indicating career aspirations for the entire sample changed across the semester, and career aspirations varied among courses. The interaction between course enrollment and time was also significant (Wilks' $\lambda = .977$, $F(3, 437) = 3.371$, $p < .05$, partial $\eta^2 = .023$), indicating that change in career aspirations across the semester was different across courses. *Post-hoc analyses revealed that students in the course for interdisciplinary honors students experienced an increase in career aspirations, but students in all other courses experienced a decrease in career aspirations. Furthermore, students in the course for engineering majors experienced the greatest decrease in aspirations for having jobs or projects in their career that involve using CS and computational thinking*. Significant pairwise comparisons between courses are also shown in Table 1.

Table 1. Changes Across the Semester in Perceived Instrumentality and Career Aspirations by Course

	CS Majors ($n = 69$)	CS/PS Majors ($n = 107$)	Engineering Majors ($n = 205$)	Business/CS Honors ($n = 56$)	All Courses ($n = 437$)
Endogenous					
Initial	4.29 (0.70)	4.00 (0.70)	3.58 (0.81)	4.46 (0.50)	3.91 (0.80)
End	3.86 (0.92)	3.64 (1.03)	2.98 (0.96)	4.36 (0.63)	3.46 (1.05)
Overall	4.08 (0.81) ^a	3.82 (0.87) ^{bd}	3.28 (0.89) ^{abc}	4.41 (0.57) ^{cd}	3.69 (0.93)
Cohen's D	-0.53	-0.41	-0.68	-0.18	-0.48
Exogenous					
Initial	2.08 (0.89)	2.18 (0.77)	2.41 (0.87)	1.64 (0.61)	2.20 (0.86)
End	2.32 (1.08)	2.49 (1.13)	2.97 (1.01)	1.71 (0.69)	2.59 (1.10)
Overall	2.20 (0.99) ^{ch}	2.34 (0.95) ^{fi}	2.69 (0.94) ^{ghi}	1.68 (0.65) ^{efg}	2.40 (0.98)
Cohen's D	0.24	0.32	0.60	0.11	0.40
Career Aspirations					
Initial	3.92 (0.90)	3.55 (0.86)	3.02 (0.76)	4.10 (0.93)	3.43 (0.93)
End	3.80 (1.09)	3.42 (1.09)	2.71 (0.95)	4.19 (0.93)	3.25 (1.15)
Overall	3.86 (1.00) ^{im}	3.49 (0.98) ^{knn}	2.87 (0.86) ^{kl}	4.15 (0.93) ⁱⁿ	3.34 (1.04)
Cohen's D	-0.12	-0.13	-0.36	0.10	-0.17

Note. $M(SD)$. Course means with different subscripts are different at $p < .05$ in pairwise comparisons.

Table 2. Summary of Univariate Follow-Up Test Results

	<i>F</i>	<i>p</i>	Partial Eta ²
Course Enrollment			
Endogenous			
Time	78.819	<.001	.154
Course	45.779	<.001	.241
Time*Course	6.571	<.001	.044
Exogenous			
Time	33.865	<.001	.073
Course	26.442	<.001	.155
Time*Course	5.270	.001	.035
Major in CS			
Endogenous			
Time	111.952	<.001	.202
Major	272.484	<.001	.382
Time*Major	6.571	<.001	.044
Exogenous			
Time	54.072	<.001	.109
Major	130.666	<.001	.229
Time*Major	27.275	<.001	.058

5.2.2 Major in CS

Mixed MANOVA was used to test whether changes in students' PI differed as a function of majoring or intending to major in CS (referred to as "major"). Group means for endogenous and exogenous instrumentality at the beginning and end of the semester are shown in Table 3. The main effect of time was significant (Wilks' $\lambda = .788$, $F(2, 440) = 59.230$, $p < .001$, partial Eta² = .212) as was the main effect of major (Wilks' $\lambda = .618$, $F(2, 440) = 136.065$, $p < .001$, partial Eta² = .382). The interaction between major and time was also significant (Wilks' $\lambda = .891$, $F(2, 440) = 26.833$, $p < .001$, partial Eta² = .109), indicating that change in PI across the semester differed between those majoring or intending to measure in CS and those not intending to major in CS. Univariate follow-up analyses revealed that both main effects and the interaction effect were significant for both endogenous and exogenous instrumentality (results summarized in Table 2). As shown in Table 3, *students not intending to major in CS experienced a larger increase in exogenous instrumentality and a larger decrease in endogenous instrumentality than students majoring or intending to major in CS.*

Mixed ANOVA was used to test whether changes in students' career aspirations differed as a function of major. Group means for career aspirations at the beginning and end of the semester are shown in Table 1. The analysis revealed a significant interaction between changes in career aspirations across the semester and plans to major in CS (Wilks' $\lambda = .949$, $F(1, 439) = 23.468$, $p < .001$, partial Eta² = .051). *Participants who planned on majoring in CS experienced a slight increase in career aspirations, whereas participants who did not plan on majoring in CS experienced a more substantial decrease.*

5.3 What is the relationship between undergraduate students' career aspirations and their endogenous and exogenous PI for a CS1 course?

We used two-step regressions to examine the relationship between PI and career aspirations. The two types of instrumentality were tested in separate regression analyses. In the first step of each analysis, we regressed PI at the end of the semester on PI at the

Table 3. Changes Across the Semester in Perceived Instrumentality and Career Aspirations by Major

	CS Majors/ Intending (<i>n</i> = 173)	Non- Majors (<i>n</i> = 270)	All Students (<i>n</i> = 443)
Endogenous			
Beginning	4.40 (0.54)	3.59 (0.78)	3.91 (0.80)
End	4.27 (0.63)	2.95 (0.93)	3.47 (1.05)
Cohen's D	-0.22	-0.75	-0.47
Exogenous			
Beginning	1.82 (0.74)	2.43 (0.84)	2.19 (0.86)
End	1.92 (0.93)	3.00 (0.99)	2.57 (1.10)
Cohen's D	0.12	0.62	0.39
Career Aspirations	(<i>n</i> = 177)	(<i>n</i> = 270)	(<i>n</i> = 447)
Beginning	4.07 (0.83)	3.02 (0.73)	3.44 (0.93)
End	4.13 (0.89)	2.68 (0.91)	3.25 (1.15)
Cohen's D	0.07	-0.41	-0.18

beginning of the semester. In the second step, we added career aspirations at the beginning of the semester and change in career aspirations as predictors. Change in career aspirations was calculated by subtracting participants' beginning of semester scores from their end of semester scores, so that positive values indicate an increase in career aspirations across the semester. This allowed us to determine whether initial career aspirations or a change in career aspirations were related to final instrumentality, after controlling for initial instrumentality.

5.3.1 Endogenous Instrumentality

In the first step, endogenous instrumentality at the beginning of the semester significantly predicted endogenous instrumentality at the end of the semester ($R^2 = .439$, $F(1, 441) = 344.904$, $p < .001$). Adding initial career aspirations and change in career aspirations significantly improved the model, ($R^2_{\text{change}} = .180$, $F_{\text{change}}(2, 439) = 103.558$, $p < .001$). Initial endogenous instrumentality ($\beta = 0.430$, $t = 11.204$, $p < .001$), initial career aspirations ($\beta = 0.356$, $t = 9.031$, $p < .001$), and change in career aspirations ($\beta = 0.422$, $t = 13.531$, $p < .001$) were all significant predictors. That is, after accounting for initial endogenous instrumentality, *initial career aspirations and change in career aspirations contributed significantly to the prediction of end-of-semester endogenous instrumentality.* As expected from theory, *higher aspirations of a career that involved CS at the start of the course and an increase in such aspirations was associated with higher endogenous instrumentality at the end of the course.*

5.3.2 Exogenous Instrumentality

In the first step, exogenous instrumentality at the beginning of the semester significantly predicted exogenous instrumentality at the end of the semester ($R^2 = .304$, $F(1, 441) = 192.572$, $p < .001$). Adding initial career aspirations and change in career aspirations significantly improved the model, ($R^2_{\text{change}} = .169$, $F_{\text{change}}(2, 439) = 70.551$, $p < .001$). Initial exogenous instrumentality ($\beta = 0.375$, $t = 9.680$, $p < .001$), initial career aspirations ($\beta = -0.366$, $t = -9.223$, $p < .001$), and change in career aspirations ($\beta = -0.358$, $t = -9.860$, $p < .001$) were all significant predictors. That is, after accounting for initial exogenous instrumentality, *initial career aspirations and change in career aspirations contributed significantly to the prediction of end-of-semester exogenous instrumentality.* As expected from theory, *higher aspirations of a career that involved CS at the start of the course and an increase in such aspirations was associated with lower exogenous instrumentality at the end of the course.*

5.4 How do changes in PI and career aspirations across the semester relate to students' CS1 learning outcomes?

Regression analysis was used to examine the relationships between participants' initial PI, changes in PI across the semester, and standardized final course grades. Changes in instrumentality were calculated by subtracting initial scores from final scores, so that positive values indicate stronger PI at the end of the semester. The overall model was significant ($R^2 = .041$, $F(4, 432) = 4.662$, $p = .001$). Only change in endogenous instrumentality was a significant predictor of standardized course grades (see Table 4). An increase in endogenous PI across the semester was associated with higher course grades ($\beta = 0.146$, $t = 2.444$, $p = .015$).

A parallel analysis was conducted using computational thinking knowledge test scores as the criterion variable. The overall model was significant ($R^2 = .156$, $F(4, 411) = 18.974$, $p < .001$). Initial exogenous instrumentality ($\beta = -.374$, $t = -5.319$, $p < .001$) and change in exogenous instrumentality ($\beta = -0.255$, $t = -4.155$, $p < .001$) were significant predictors, and change in endogenous instrumentality ($\beta = 0.111$, $t = 1.923$, $p = .055$) trended toward significance (see Table 4). These results indicate that *lower exogenous instrumentality at the beginning of the semester and a decrease in exogenous instrumentality were associated with higher scores on the computational thinking knowledge test*.

Regression analysis was also used to examine the relationships between participants' initial career aspirations, changes in career aspirations across the semester, and standardized final course

Table 4. Relationships of Perceived Instrumentality and Career Aspirations with Achievement.

	β	t	p	R^2	Adj. R^2
Instrumentality					
Course grades				.041*	.033
Initial endogenous	-.048	-0.691	.490		
Initial exogenous	-.060	-0.824	.410		
Endogenous change	.146	2.444	.015		
Exogenous change	-.082	-1.291	.197		
Knowledge test				.156**	.148
Initial endogenous	-.106	-1.536	.125		
Initial exogenous	-.374	-5.319	<.001		
Endogenous change	.111	1.923	.055		
Exogenous change	-.255	-4.155	<.001		
Career Aspirations					
Course grades				.073**	.069
Initial aspirations	.050	1.060	.290		
Aspirations change	.278	5.860	<.001		
Knowledge test				.120**	.115
Initial aspirations	.273	5.766	<.001		
Aspirations change	.283	5.968	<.001		

Note. * $p < .01$, ** $p < .001$

grades. Changes in career aspirations were calculated by subtracting initial scores from final scores, so that positive values indicate stronger career aspirations at the end of the semester. The overall model was significant ($R^2 = .073$, $F(2, 438) = 17.249$, $p < .001$). Only change in career aspirations was a significant predictor of standardized course grades (see Table 4). *An increase in career aspirations across the semester was associated with higher course grades* ($\beta = 0.278$, $t = 5.860$, $p < .001$).

A parallel analysis was conducted using computational thinking knowledge test scores as the criterion variable. The overall model was significant ($R^2 = .120$, $F(2, 413) = 28.041$, $p < .001$). Initial aspirations ($\beta = .273$, $t = 5.766$, $p < .001$) and change in career aspirations ($\beta = .283$, $t = 5.968$, $p < .001$) were significant predictors (see Table 4). These results indicate that *higher career aspirations at the beginning of the semester and an increase in career aspirations were associated with higher scores on the computational thinking knowledge test*.

Taken together, these results indicate that *PI and career aspirations are more strongly related to the computational thinking knowledge test than standardized course grades*.

6. DISCUSSION

6.1 Grand Summary of Findings

The results of this study indicate that CS1 students' PI and career aspirations change from the beginning to the end of the semester. On average, perception of exogenous instrumentality increases, perception of endogenous instrumentality decreases, and aspirations to pursue a career in CS decreases. However, these trends differed as a function of course enrollment and major.

First, *overall levels of PI and patterns of change in PI were different in different courses*. Unsurprisingly, students in the course for CS majors and the course for students in the business/CS honors program reported the highest levels of endogenous instrumentality and the lowest levels of exogenous instrumentality at both the beginning and end of the semester. Because most students in these two classes have a major in CS or a minor in CS, it makes sense that they would see the content of their CS1 course as being meaningfully connected to their future goals (endogenous instrumentality) while placing less emphasis on only the utility of obtaining a grade for future goal attainment (exogenous instrumentality). Students in the business/CS honors program appeared to hold on to their initial higher endogenous PI and lower exogenous PI across the semester better than the CS majors as they exhibited less change in their PI during the semester. In contrast, students in the course for engineering majors reported the lowest levels of endogenous instrumentality and the highest levels of exogenous instrumentality at the beginning of the semester, and then proceeded to exhibit the greatest decrease in endogenous PI and increase in exogenous PI. In fact, at the end of the semester, they reported comparable levels of the two types of PI. This indicates that, compared to students in other courses, the students in the introductory CS course for engineering majors initially saw less of a connection between the learning the course content and their future goals, and over time their already weak perceived connection between the content and their goals weakened *further* still. At the same time, these students initially saw more of a utilitarian-only connection between getting a grade in the course and their future goals than did other students, and during the semester this utilitarian-only instrumentality increased *even more* than students in the other CS1 classes.

Second, *overall levels of career aspirations and change in career aspirations were different in different courses*. Aspirations to pursue a career that utilizes a substantial amount of CS applications and computational thinking decreased on average for the entire sample. Students in the business/CS honors program, however, demonstrated a small, but significant increase in their career aspirations, meaning they were more aspiring of a CS-related career at the end of class than when they started. Students in the course for engineering majors started with the lowest aspirations for having CS and computational thinking in their career and exhibited the greatest decrease in these career aspirations. And, students in the course for CS majors and the course for both CS and physical science majors exhibited similarly small declines in career aspirations, though students in the CS course reported higher career aspirations at both time points. In general, these results indicate that (1) students differ in the degree to which they aspire to pursue a career that utilizes a substantial amount of computer science applications and computational thinking when they enter their CS1 courses, and (2) while students in most of the CS1 courses decreased in career aspirations, students in at least one course increased in their CS career aspirations.

Third, *overall levels of PI, career aspirations, and patterns of change in PI and career aspirations differed according to whether or not students were majoring or intending to major in CS*. At both time points, students majoring or intending to major in CS reported lower exogenous instrumentality and higher endogenous instrumentality than those *not* intending to major in CS. The overall trend of increasing exogenous instrumentality and decreasing endogenous instrumentality was present in both groups, but the average changes were substantially larger for students who did not intend to major in CS. That is, *students majoring or intending to major in CS primarily felt that the CS1 course was connected to their future goals because of what they were learning in the course, rather than because of the impact their grade would have on their future*. Students not intending to major in CS initially indicated similar perceptions, though the perceived connection between course content and future goals was weaker, and the perceived connection between grades and future goals was stronger. By the end of the semester, the difference in magnitude for endogenous and exogenous instrumentality had vanished for students not intending to major in CS.

Additionally, students who did not intend to major in CS initially reported lower career aspirations than those majoring or intending to major in CS. By the end of the semester, *non-majors had even less of a desire to pursue a career that involved a substantial amount of CS applications and computational thinking; whereas, those majoring or intending to major in CS reported slightly higher aspirations for a career in CS*. These results suggest rather clearly that PI, career aspirations, and the way they change during a CS1 course differ substantially among those who are majoring or not majoring in CS.

Fourth, consistent with prior research and theory [1, 6, 8, 14, 15], *higher career aspirations significantly predicted higher endogenous PI and lower exogenous PI*. Importantly, our findings show that *students who increase in their aspirations for a CS-related career across the semester have higher instrumentality for learning the course content*.

Fifth, *PI and career aspirations were more strongly related to scores on the computational thinking knowledge test than standardized course grades*. Findings were consistent with prior studies showing PI and career aspirations to be associated with higher achievement and learning [6, 15, 24]. Interestingly, changes in

endogenous instrumentality and changes in career aspirations were the only individually significant predictors of standardized course grades, and their predictive power was rather weak. However, exogenous instrumentality and career aspirations were both predictive of scores on the computational thinking knowledge test. That is, higher initial exogenous instrumentality and an increase in exogenous instrumentality were associated with lower scores, and higher career aspirations and an increase in career aspirations predicted higher scores. The computational thinking knowledge test is a cumulative test that targets deeper understanding and more long-term retention of the CS principles and skills taught in these CS1 courses, so it makes sense that weaker perceptions of the primary value of a course being in the grade one receives (rather than the content) and aspirations to pursue a career in CS would be associated with higher scores on this test.

The findings presented here must be interpreted in light of the limitations of this study. First, our sample was drawn from CS1 courses at a single institution. More research is needed to determine whether these findings can be generalized to more advanced CS courses or other institutions. Given that the sample in this study contained 447 students from a variety of programs enrolled in five different classes taught by five instructors, it is reasonable to believe the results could be replicated in other studies of undergraduate CS students. Furthermore, the CS1 courses from which our sample was drawn are tailored for different groups of students, which is fairly atypical of CS1 courses. It is unclear whether or how this tailoring and grouping of students might impact PI, career aspirations, and their change over time. Second, PI and career aspirations were only measured at the beginning or end of the semester, precluding the possibility of more complex analyses that can detect non-linear change over time. It is possible that the changes in PI and career aspirations do not follow a steady, monotonic trajectory, and future research examining PI and career aspirations at more than two time points should test for non-linear change.

6.2 Implications for CS Educators

There is concern about attracting and retaining students in STEM-related fields [22, 30], including CS [2, 10]. Given this concern, it is important for CS educators to be aware of how students might conceptualize the value of their CS1 courses. The findings from this study suggest students' conceptions of the connection between CS1 courses and their futures may change while students are taking the course. The decrease in endogenous PI and increase in exogenous PI suggests that students gradually see their grade in the course as more important and the content as less important. Previous research has connected PI to the use of adaptive learning strategies [13] and the amount of time spent studying [14], as well as academic achievement [24]. Therefore, intentionally fostering PI could be one way to increase meaningful long-term learning of CS content.

CS educators can positively influence undergraduate CS students' PI by helping them see the connections between course content and future goals. It is important to point out such connections because students who perceive the instrumentality of CS1 courses as primarily exogenous (i.e., the grade earned will impact their future) rather than endogenous (i.e., what is learned will impact their future) might be less likely to take additional CS courses and less likely to consider the possibility of majoring in CS. However, students who perceive the instrumentality of CS1 course content as primarily endogenous are probably more likely to take additional CS courses and more likely to consider majoring in CS.

Results of intervention studies [23] indicate that students' PI can be positively impacted through relatively short interventions that involve prompting students to think about direct connections between course material and their future goals. Though the connections between a course and students' futures may seem obvious to the instructor, students might not see those connections without external prompting. For example, an instructor could promote endogenous PI by having students respond to a brief writing prompt about how a concept or learning activity is connected to the types of problems they are likely to encounter in a future job. Having students share the connections they see can further expand students' understanding of how course content is connected to their futures. Activities such as this one can help students see the value in mastering the content of CS courses.

7. CONCLUSION

In this study, we found that CS1 students' PI and career aspirations changed over the course of a single semester. This is an important finding as it indicates that both PI and career aspirations are somewhat dynamic and influenced by students' experiences during the course. In general, students' experiences during the semester caused them to decrease in endogenous PI to learn the course material and increase in exogenous PI for the more utilitarian goal of getting a grade. Of course, within these general patterns, some students did increase in endogenous PI and decrease in exogenous PI and these patterns were associated with higher learning and achievement. Similarly, although on average career aspirations decreased across the semester, those students who increased in their career aspirations also increased in their endogenous PI and their learning of course material. Students who indicated majoring or intending to major/minor in CS were more resistant to declines in endogenous PI and actually increased in career aspirations; whereas non-CS majors had significant decreases in both. This suggests that the experiences in CS1 classes are generally positive for CS majors; but rather negative for non-CS majors, even when the primary course for non-majors (the engineering major course) was specifically tailored for these non-majors. Results help clarify the differences found for initial PI [27] and end-of-semester PI [24]. Because of the rather large changes in PI across the semester found in this study, it makes sense that students' initial PI might be relatively unassociated with course achievement.

Given the emphasis placed on retention in CS and other STEM-related courses [2, 10, 22, 30], particularly retention of underrepresented populations, we believe it is important for CS educators to understand the connections between PI and achievement in CS courses. By helping students see clear connections between what they are learning in a CS1 course and their future goals, CS educators may be able to positively impact student motivation, achievement, and retention in CS courses and computing-related majors.

There are at least two possibilities to generally explain the findings reported in this paper. The first is that students begin their CS1 course with somewhat inaccurate views about the field of CS, how computational thinking and CS may connect to their future career goals, what it means to be a computer scientist, and how they would use or apply CS knowledge in their careers. Then, as they complete their first CS course and learn more about CS, there is a shift in their understanding of how CS does or does not relate to these future goals. The second possibility is that students have an accurate understanding about the field of CS and how it connects to their future goals, but as they complete their first CS course, there is a shift in students' future goals. In the

former case, constructing a more accurate representation of CS and its connection to future plans is what drives the shift in instrumentality and career aspirations. In the latter case, it is the shift in students' future plans that drives the change in instrumentality and career aspirations. Future research should explore these, and other, possible explanations for the shifts in PI and career aspirations during CS1 courses. Future research is also needed to identify (1) how changes in PI and career aspirations impact subsequent enrollment in CS courses, (2) the relationship between PI and career aspirations and retention in CS majors, and (3) whether similar shifts in PI and career aspirations occur in other STEM courses, including upper-level CS courses.

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9. REFERENCES

- [1] Alpay, E., Ahearn, A. L., Graham, R. H., and Bull, A. M. J. 2008. Student enthusiasm for engineering: charting changes in student aspirations and motivation. *European J. of Engin. Ed.* 33(5-6), 573-585.
- [2] Barker, L. J., M. O'Neill, and N. Kazim 2014. Framing Classroom Climate for Student Learning and Retention in Computer Science. In *Proc. of the 45th ACM Technical Symposium on Comp. Sci. Educ. (SIGCSE'2014)*, 319-324
- [3] Committee on Prospering in the Global Economy of the 21st Century 2007. *Rising Above the Gathering Storm*. Washington, DC: National Academies Press
- [4] Flanagan, A. E., Peteranetz, M. S., Shell, D. F., and Soh, L-K (2015). Exploring changes in computer science students' implicit theories of intelligence across the semester. In *Proc. of ICER'15 (Omaha, NE)*, 161-168.
- [5] Forte, A., and M. Guzdial 2005. Motivation and Nonmajors in Computer Science: Identifying Discrete Audiences for Introductory Courses. *IEEE Trans. on Ed.*, 48(2), 248-253
- [6] Greene, B. A., & DeBacker, T. K. 2004. Gender and orientations toward the future: Links to motivation. *Ed. Psych. Review* 16(2), 91-120.
- [7] Hazley, M.P., Shell, D.F., Soh, L.K., Miller, L.D., Chiriacescu, V., and Ingraham, E. 2014. Changes in student goal orientations across the semester in undergraduate computer science courses in *Proceedings Frontiers in Education Conference*, (Madrid, Spain, 2014), IEEE, 1-7.
- [8] Hilpert, J.C., Carrion, M.L, Husman, J., and Baughman, L. 2011. Engineering futures: Female students, careers, and work/life balance. Published in the conference proceedings of the *41st ASEE/IEEE Frontiers in Ed. Conference*.
- [9] Hilpert, J.C., Husman, J., Stump, G.S., Kim, W., Chung, W.T., and Duggan, M.A. 2012. Examining students' future time perspective: Pathways to knowledge building. *Japanese Psych. Research* 54(3), 229-240
- [10] Haungs, M., C. Clark, J. Clements, and D. Janzen 2012. Improving First-Year Success and Retention through Interest-Based CS0 Courses, in *Proc. 43rd ACM Technical Symposium on Comp. Sci. Educ. (SIGCSE'2012)*, 589-594.
- [11] Husman, J., Derryberry, W.P, Crowson, H.M., and Lomax, R. 2004. Instrumentality, task value, and intrinsic motivation: Making sense of their independent interdependence. *Contemporary Educational Psychology* 29, 63-76.

- [12] Husman, J. and Lens, W. 1999. The role of the future in student motivation. *Educational Psychologist* 34(2), 113-125.
- [13] Husman, J. and Hilpert, J. 2007. The Intersection of Students' Perceptions of Instrumentality, Self-Efficacy, and Goal Orientations in an Online Mathematics Course. *Zeitschrift für Pädagogische Psychologie/ German Journal of Educational Psychology* 21, 229-239.
- [14] Lens, W., Simons, J., and Dewitte, S. 2001. Student motivation and self-regulation as a function of future time perspective and perceived instrumentality. In S. Volet and S. Järvelä (Eds.) *Motivation and learning contexts: Theoretical advances and methodological implications*. (233-248). Pergamon Press.
- [15] Leondari, A. 2007. Future time perspective, possible selves, and academic achievement. *New Directions for Adult and Continuing Ed.* 2007(114), 17-26.
- [16] McGill, M. M. 2012. Learning to Program with Personal Robots: Influences on Student Motivation. *ACM Trans. on Comp. Educ.*, 12(1), article 4.
- [17] Miller, R.B., DeBacker, T.K., and Greene, B.A. 1999. Perceived instrumentality and academics: The link to task valuing. *J. of Instruc. Psych.* 26(4), 250-260.
- [18] National Center for Education Statistics 2014. *Digest of Education Statistics*. Washington, DC: U.S. Dept. of Ed.
- [19] Authors Suppressed for Anonymity.
- [20] Pekrun, R., vom Hofe, R., Blum, W., Frenzel, A. C., Goetz, T., and Wartha, S. 2007. Development of mathematical competencies in adolescence: The PALMA longitudinal study. In M. Prenzel (Ed.), *Studies on the educational quality of schools* (pp. 17-37). Münster, Germany: Waxmann..
- [21] Porter, L., M. Guzdial, C. McDowell, and B. Simon 2013. Success in Introductory Programming: What Works?, *Communications of the ACM*, 58(8), 34-36.
- [22] President's Council of Advisors on Science and Technology 2012. *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics*. Washington, DC: Executive Office of the President of the United States.
- [23] Puruhito, K., Husman, J., Hilpert, J.C., Ganesh, T., and Stump, G. 2011. Increasing instrumentality without decreasing instructional time: An intervention for engineering students. Published in the *Conference Proceedings of the 41st ASEE/IEEE Frontiers in Education Conference*.
- [24] Shell, D.F., Hazley, M.P., Soh, L.K., Ingraham, E., and Ramsay, S. 2013. Associations of students' creativity, motivation, and self-regulation with learning and achievement in college computer science courses in *Proceedings of the Frontiers in Education Conference*, (Oklahoma City, Oklahoma, 2013), IEEE, 1637-1643.
- [25] Shell, D. F., Hazley, M. P., Soh, L.-K., Miller, L. D., Chiriacescu, V. and Ingraham, E. 2014. Improving learning of computational thinking using computational creativity exercises in a college CS1 computer science course for engineers. In *Proc. 44th Annual Frontiers in Ed. (FIE) Conference*, (Madrid, Spain), 3029-3035.
- [26] Shell, D.F. and Soh, L.K. 2013. Profiles of motivated self-regulation in college computer science courses: Differences in major versus required non-major courses. *J. of Sci. Ed. and Tech.* 22 (Feb. 2013), 899-913. DOI= 10.1007/s10956-013-9437-9
- [27] Shell, D. F., Soh, L.-K., Flanigan, A. E., and Peteranetz, M. S. 2016. Students' initial course motivation and their achievement and retention in college CS1 courses. In *Proc. 47th ACM Technical Symposium on Computer Science Education (SIGCSE'2016)* (Memphis, TN), 639-644).
- [28] Simons, J., Dewitte, S., and Lens, W. 2004. The role of different types of instrumentality in motivation, study strategies, and performance: Know why you learn, so you'll know what you learn! *British Journal of Educational Psychology* 74, 343-360.
- [29] Wing, J. 2006. Computational Thinking. *CACM*, 49, 33-35.
- [30] Watkins, J., and Mazur, E. 2013. Retaining students in science, technology, engineering, and mathematics (STEM) majors. *J. of Col. Sci. Teach.* 42(5), 36-41.
- [31] Xie, Y. and Killewald, A. A. 2012. *Is American science in decline?* Cambridge, MA: Harvard University Press. doi:10.4159/harvard.9780674065048.