Tracking Undergraduate Students' Perception of Early Exposure to Practical Computing Skills Over Time

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***Abstract*—This innovative practice full paper describes the impact of early exposure to practical computing skills on students' learning experiences. In a longitudinal study, we evaluated the effects of incorporating co-curricular activities and hands-on skills into the undergraduate Computer Science (CS) curriculum, while also tracking students' sustained interest and utilization of these skills over time. Over a three-year period, more than 900 students majoring in CS were surveyed at the end of a required introductory course (post-course survey) that introduced various computing practical skills. These skills, encompassing topics such as version control, SQL, command line tools, and web development, were strategically integrated into the course to enhance students' engagement and equip them for subsequent co-curricular computing endeavors. Students' interests in these topics were measured at the completion of the course and again re-evaluated during their senior year three years later (senior-year survey). In the senior year, over 500 students responded to the survey. Similar questions related to interest, motivation, and the use of skills were asked in this follow-up survey. The results of the post-course and senior-year surveys were compared at the aggregated level. We were also able to map the responses of 68 students individually and compare their post-course and senior-year survey responses. The results of the individual students were consistent with the overall aggregated data between post-course and senior-year data. Our data analysis offers information on the timing and occasion of students applying practical skills, their sentiments regarding co-curricular activities, and the favorable influence of practical skills on the overall student experience. As students mature and accumulate experiences in their academic journey, their perceptions about these early exposures and practical skills also evolve. By the time they reach their senior year, basic practical skills do not appear as crucial, given their acquired proficiency. Nevertheless, this observation is significant since educators may not always be attuned to the challenges faced by novice students, emphasizing the importance of early exposure. Additionally, our longitudinal results affirms that both the utility and interest levels persist over the span of their undergraduate degree, reinforcing sustained motivation.**

***Index Terms*—Co-curricular activities, Problem-solving skills, Comfort level, Early exposure.**

I. Introduction

Success and persistence in the computer science pipeline have been the topic of many research studies over the past four decades. Various research works have examined personal and behavioral factors, such as self-regulation, self-efficacy, motivation, and study habits, as potential influences on the students' perception and persistence in the computing field [1]–[5]. Additionally, academic factors such as high school preparation, prior computing experience, and overall student GPA have been identified as variables that could impact a student's success in introductory CS classes [6]. Other indicators such as student comfort, social integration, and sense of belonging have also been found to play significant roles in the perseverance of students in engineering [7], [8] and the computing-related fields [9], [10].

Engagement in co-curricular computing programs such as hackathons [11], coding clubs [12]–[14], Capture the Flag (CFT) competitions [15], internships, undergraduate research, and service-learning projects [16], have been shown to enhance retention, persistence, and a sense of belonging among CS students. Several studies focusing on underrepresented groups in the STEM fields suggest that engaging in co-curricular activities positively affects their self-efficacy, confidence, and sense of belonging [5], [17]–[21]. Moreover, involvement in these pursuits frequently provides students with practical skills that prove advantageous for future professional endeavors.

Typically, these activities are more accessible to those with previous exposure to the field during their primary and secondary education years. Students who have attended coding camps, taken Advanced Placement (AP) CS courses, or had access to computing resources at home are more likely to participate in and gain advantages from co-curricular initiatives. However, not every student majoring in computer science enters college with prior experience in the field. Previous exposure to such opportunities significantly contributes to the development of computer science skills, and the lack of such exposure could potentially put a student at a disadvantage compared to their classmates and peers.

A mechanism to better understand student persistence is to look into the change in perception and interest of students over time as they progress through their studies. For example, in one longitudinal study [22] researchers examined students' perception of the CS curriculum. This qualitative study showed that there is a positive relationship between comfort and perseverance, such that the more technical students felt more comfortable and successful in their courses. Studies also have shown that woman students have lower self-efficacy than their male counterparts [23]. Given current efforts surrounding recruitment, retention, and diversity in the computing field [24], it is critical that students' experiences and potential changes in their perceptions of the computing field are examined more closely.

In this paper, the impact of early exposure to practical computing skills on students' learning experiences is examined in a three year longitudinal study. In the context of this study, we define "early" exposure as introducing concepts early on in the post-secondarily CS curriculum. In our institution, students become CS majors at the end of their first year of studies (end of freshman year), and they only begin to take CS classes starting their second year (sophomore year). Traditionally, practical skills such as command line, SQL, and version control are not addressed until students have taken several introductory programming courses and later during the second or third year of their CS studies. Early exposure in introductory CS courses and at the start of the CS curriculum can help improve students perceptions of themselves and their coursework.

In this work, we examined the effects of incorporating co-curricular activities and hands-on skills into a lower level undergraduate CS course, while also tracking students' sustained interest and utilization of these skills over time. The innovation in this study is the ability to measure students' interest at the two ends of their academic journey. Once at the start of their CS undergraduate curriculum, and once at the end of their senior year. The effects of these early post-secondary level exposures to computing topics, given that most students typically have not been exposed to CS or the related skills in high school or before, can help develop early intervention strategies that can improve retention and perception for underrepresented groups in the computing field at the post-secondarily level [25]. In this paper we will share the findings of this multi-year study that examined the experiences of computer science undergraduate students at Virginia Tech.

II. Conceptual Framework and Research Questions

This study is guided by Bandura's *Social Cognitive Theory* [26] to better understand the context in which students perceive practical skills during their undergraduate studies, and how this influences their choices and plans for future interest.

The Social Cognitive Theory explains how human behavior is influenced by personal experiences, cognitive factors, social interactions and the environmental cues that surround an individual. In recent years, this theory has been expanded to computer science education research involving motivation and self-regulation [27]–[29]. Some students have very different backgrounds when entering the university. Students have different skill levels that can depend on prior computer science extracurricular activities, their living environment, and social aspects. Students who have participated in online coding challenges, hackathons, or coding camps in high school have experienced different environments that might affect how they view practical skills. The students' living environment can also be accounted for by the social cognitive theory. Whether a student lives in a dormitory, surrounded by other students, or lives off campus and is more isolated can have an affect on the overall experience of that students especially during the early years of an undergraduate degree. Lastly, students' social interactions may affect their overall perception of the field. For example, the time students spend in the CS department's student lounge among other computer science students can improve their perception and sense of belonging. Social cognitive theory can help explain the context in which students perceive practical skills and how these feelings might change over time as they progress through their undergraduate years.

Guided by this theory, the focus of this work is to examine the effects of incorporating practical skills and its impact on students' academic success, preparation for future careers, and comfort level with co-curricular activities as well as the changes in students' perception of acquired skills as they mature in their undergraduate studies. Our research questions are as follows:

- RQ1: Is there evidence that learning practical skills in the curriculum has a positive impact on students' academic growth and career preparations?
- RQ2: How do comfort level and influence of practical skills evolve throughout the undergraduate years?
- RQ3: Does the perception of undergraduate computer science students about early exposure to practical skills change as they progress through their degree?

III. Institutional Background

Our study was conducted at Virginia Tech (VT) which is a large public research university with more than 30,000 undergraduate students and a rapidly growing CS department. The current CS undergraduate enrollment is around 1,600 students. About 600 students graduated with an undergraduate degree from the CS department in the 2023-2024 academic year. Computer Science is one of the departments within the College of Engineering at our institution. Students are admitted to the College of Engineering as General Engineering majors in their first year when they take general engineering requirement courses. Students typically declare a major at the end of their first year and officially become CS majors at the beginning of their second year (sophomore year) of studies.

All students who declare a CS major in our department, regardless of their background or prior experience, are required to take an introductory course in problem-solving, unless for a small fraction of students who can get transfer credits for this course. We conducted our initial survey in this course which we will refer to as the *post-course survey* throughout this paper. The CS majors were subsequently surveyed again at the end of their studies during a required senior seminar course which most CS students take in their final semester. We will refer to this survey as *senior-year survey* throughout this paper.

For the purposes of this study, we define "early exposure" as exposure at the entry point to the CS undergraduate major at our institution, when students declare CS major. For most students this time point is at the beginning of the second year of their studies.

A. *Practical Skills in a Problem Solving Course*

All students majoring in Computer Science at VT are required to take an introductory problem-solving course, except for a few who can get transfer credits for this course. This course was redesigned in Fall 2018 to broaden access and provide early exposure to computing topics as a student enters the CS major. The redesign of the course was made to bridge the gap between students who have had opportunities to gain experience in the field prior to entering the university versus those who lack exposure, resources, and experience [30]. There are usually 4 sections of 60-80 students per semester for this course. Topics covered in the course include concepts that could be useful during internships, undergraduate research, upper-level courses, and co-curricular activities such as hackathons and coding clubs. Practical skills such as command line, git, version control, Wireshark, and the use of Python and SQL to explore data science concepts are incorporated into the course. Students also participate in Capture the Flag (CTF) type exercises and develop websites as a way to introduce them to more co-curricular activities. The intention of including such activities is to provide an opportunity for students to practice these applied skills collaboratively in a team, in a comfortable environment, and with appropriate support throughout, thus improving the equity of experience for students who had or had not previously used such skills [30], [31].

B. *Surveys Information*

Over three years, starting in Fall 2018, the students enrolled in this course participated in a survey to reflect on their experiences with early exposure to practical skills. The survey which was conducted at the end of the course while their experience was still easily recollected, included multiple-choice, Likert-type, and open-ended questions where students reported on how the skills introduced in that class influenced their overall computing experience. There were over 900 student responses to the survey across several semesters.

Another survey was administered during a senior seminar course that all senior CS students take, and included similar styled questions as the post-course survey. Over 500 students took this survey. Additionally, we were able to match the IDs of 68 students who completed both surveys (post-course survey and also senior-year survey), allowing us to directly compare the experiences of this subgroup of our participants.

Both surveys were given as an assignment and the completion counted as participation points for the students. The students could opt in to have their responses used for this research. Our results are only based on the analysis of the data collected from students who gave us consent and opted in to participate in the research study. This project has an approved IRB from our office of institutional research.

The post-course survey collected data did not include demographic information for the 957 students who participated in it. However, demographic data was collected on the senior-year survey. Table I shows the distribution of the responses based on gender and race for students who completed the senior-year survey to reflect on their experience in the problem-solving course that they took in their first semester as CS majors. The majority of the students in this survey are male at 75% (386). Participants' race ranges from 41% White, 44% Asian, and 15% others.

For gender, we used male and female categories since these are the two categories that our institution has used to identify gender. For demographic categories, we used a similar grouping as in other Computing Research Association (CRA) publications, but our data does not separate non-resident students from domestic students. To protect the anonymity of students in categories with small sample sizes (as required by our IRB guideline), we have combined a few groups together. URM (Underrepresented Minorities) includes Black and African American, Hispanic, Native American, and multiracial students. Students without a disclosed race are marked as Not Reported.

TABLE I
SENIOR SURVEY RESPONDENTS DISTRIBUTION

Gender	Male	386 (75%)
	Female	92 (18%)
	Other/NR*	34 (7%)
Race	White	210 (41%)
	Asian	228 (44%)
	URM‡	60 (12%)
	NR*	14 (3%)
Total		512 (100%)

*NR: Not Reported; ‡ URM: Underrepresented Minorities

We limited our senior-year data inclusion criteria to those survey respondents who had completed the problem-solving course at our institution (with consent to use their data) and excluded data from students who indicated that they did not complete this course at our institution. This inevitability excludes transfer students who received transfer credits for this course but is consistent for our analysis since we do not capture the experience of those students in the original problem solving course.

The students were asked Likert-style questions involving the students' perception of the course using the questions listed below in both post-course and senior-year surveys. The questions were written to gauge students' perceptions of usefulness and interest and also to reflect on their CS self-efficacy. The questions were inspired by the MUSIC (eMpowerment, Usefulness, Success, Interest, and Caring) model of motivation [32]. The MUSIC model was developed as a research-based model to explain factors in the motivational climate that affect students' motivation to engage in activities, such as courses and class assignments. Some of our questions were inspired by the questionnaire used in this model, but were adjusted to address our own research questions.

Below is the list of the questions used in our surveys:

- Q1: This course was useful to me.
- Q2: This course was interesting to me.
- Q3: I improved my problem solving and technical skills in this course.
- Q4: The knowledge and experience I gained from this course has prepared me to be more successful in future courses.
- Q5: The knowledge and experience I gained from this course has prepared me to be more successful in my career.
- Q6: The knowledge and experience I gained from this course has or will influence my computer science activities outside of my coursework.

In post-course survey, in addition to Likert-type questions, students were asked to comment on their experience and reasons for participating or not participating in practical computing activities outside of the classroom in open-ended questions.

IV. Results

In this section, the collected survey data will be analyzed. We first look at the result of post-course survey which can help us answer RQ1 and demonstrate the effects of practical skills on students' overall experience and the usefulness of these skills in various academic and career aspects of a student's journey throughout their undergraduate years. We will then delve into senior-year survey data, where we can answer RQ2 about the change in perception and persistence.

A. Post-Course Survey Results- RQ1

Our first research question was: *Is there evidence that learning practical skills in the curriculum has a positive impact on students' academic growth and career preparations?* To answer this question the responses of 957 students who were enrolled in the problem solving course were analyzed. The result is summarized in Table II. Initially, 76% (727) of students agreed that the practical skills introduced during the course were useful, with 72% (690) agreeing that they anticipate that these skills would enhance their academic or career success in the future. This emphasizes the benefits of practical skills and co-curricular activities for future success.

TABLE II
Response to Likert-style Questions- Post-Course Survey

Question	**Strongly Disagree/ Disagree**	**Neutral**	**Agree/ Strongly Agree**
Q1	12%	12%	76%
Q2	11%	15%	74%
Q3	10%	16%	74%
Q4	12%	16%	72%
Q5	11%	17%	72%
Q6	15%	17%	68%

In addition, students responded to questions about their engagement in co-curricular activities. A significant 74% (708) of students reported engagement in computing activities outside of their coursework. Many students reported that they had been using practical computing skills outside of their coursework for personal programming projects. Notably, 59% (568) participated in personal programming projects. Out of the students who were engaged in personal programming projects, 74% were engaged repeatedly. This recurring engagement underscores the value students place on personal programming projects and the practical skills acquired through co-curricular activities. Students reported that personal projects were the co-curricular activity they were the most comfortable with out of the options: personal programming projects, group programming projects, undergraduate research, CTFs, online coding challenges, and hackathons.

In addition to Likert-type questions, students were asked to comment on their experience and reasons for participation in practical computing activities outside of the classroom. We had two categories of students:

1) Those who participated: We asked the students who had said they participated in computing activities outside of the classroom to comment on their reason for participating in activities outside of the classroom by asking the following open-ended question: "Please explain why you have participated in computing activities outside of coursework?" A qualitative analysis was performed on the responses using a Python script to identify the most frequently mentioned words. This script aided in a thematic analysis of the data. Prominent themes were revealed from the qualitative analysis and can be found in Tables III, IV, and V. A significant proportion (66%) of the 620 responses expressed participation in extracurricular activities as enjoyable, indicating interest and enthusiasm among students. Another, 164 responses emphasized the desire to acquire knowledge and skills, reflecting students' efforts to improve. Additionally, 15 students participated in extracurricular activities to challenge themselves. Table III shows the three common themes that emerged after analyzing 620 responses. Table IV shows sample responses supporting the themes.

TABLE III
Reasons for Participation in Computing Activities

Theme	**Keywords**	**Total**
Desire	enjoy; interest; want; like; fun;	412 (66%)
Acquire	learn; gain; improve; expand; understand; grow; increase;	164 (26%)
Challenge	challenge; challenging	15 (2%)

2) Those who did not participate: Students who did not participate in any co-curricular activities were asked about their reasons for not participating. Among the students who reported not having engaged in co-curricular activities, 54% agreed that they were interested, indicating a desire to participate. However, over 54% stated time constraints or inadequate background as barriers to participation. Additionally, 62% expressed that the social atmosphere was not for them, highlighting the need to adjust the social environment of co-

TABLE IV
SAMPLE RESPONSES TO AN OPEN-ENDED QUESTION FOR THOSE WHO PARTICIPATED

Desire	
Student 1	Because its interesting to me and I have fun doing it.
Student 2	It is fun to explore the ideas that my friends and I have using computer science.
Acquire	
Student 3	To improve my skills and add to my resume.
Student 4	Gaining experience is much more valuable than the grades I receive on my coursework in my opinion.
Challenge	
Student 5	I participated in these computing activities in order to continue to challenge myself.
Student 6	Because they challenge my mind and I like to solve problems.

curricular and provide welcoming opportunities within the curriculum. An introduction to more practical skills within the curriculum could help students feel more prepared and possibly more comfortable.

Fig. 1 visualizes the students' reasons for not participating on a five-point Likert-style scale. The top reasons that students did not participate was because they did not know how to participate or they did not have a network of peers to complete projects or attend activities with. An introduction to more practical skills within the curriculum could help students feel more prepared and possibly more comfortable.

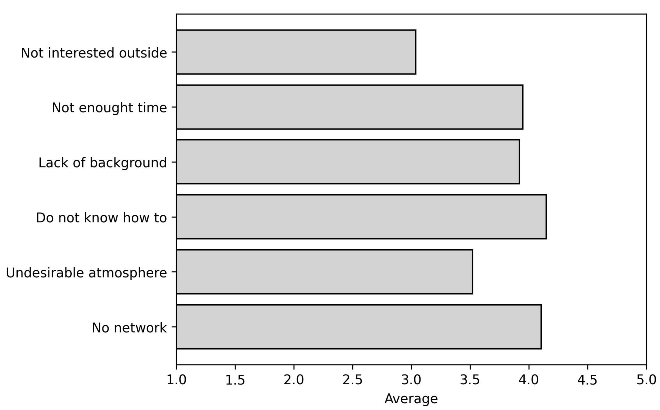

Fig. 1. Reasons for not participation in computing activities.

Students were also given a chance to write about their lack of participation, and some sample responses can be found in Table V. The qualitative responses highlight self-efficacy as a significant concern among students, with many expressing concerns about their skill levels or background.

This emphasizes the importance of early exposure to practical skills to encourage greater participation in co-curricular activities. Students A and B display concerns of lacking confidence preventing their participation. Students E and F also show similar concerns with regard to their background not being sufficient enough. The remaining students from Table V express time constraints. In summary, some students have acknowledged the importance of practical skills, but don't feel comfortable enough to engage in projects outside of their own personal spaces.

TABLE V
SAMPLE RESPONSES TO AN OPEN-ENDED QUESTION ABOUT STUDENTS' REASONING FOR NOT PARTICIPATING IN COMPUTING OUTSIDE OF COURSE WORK

Lack of Confidence	
Student A	I am not confident in my abilities as a computer scientist outside of class.
Student B	I would love to explore more opportunities to do computing activities outside of my coursework, but I'm not confident in my skill level.
Time Constraint	
Student C	I do not have much experience yet and am worried I won't be able to spend enough time doing too many things because of the excessive amount of homework I have.
Student D	I enjoy participating in computing activities outside of my coursework, however, I find that I don't have a lot of time to do them.
Lack of Background	
Student E	I haven't participated in Online Coding Challenges, Hackathons, CTFs, or Undergraduate Research, and I'm not sure what to expect. I'm worried that I'll be inadequate for my team. I'm most comfortable with Person Programming Projects because I can test out some ideas.
Student F	I still feel inexperienced which is why I'm somewhat apprehensive towards some computing activities.

B. Senior-Year Survey Results and Comparison- RQ2

Our second research question was: *How do comfort level and influence of practical skills evolve throughout the undergraduate years?* To answer this question, we first analyzed the responses to a senior-year survey and then compared the results to the post-course responses. Over the span of several years, 512 students who had previously taken the redesigned problem-solving course responded to a senior-year survey about their undergraduate experience, approximately three years after completing the course. They were asked to reflect on the practical skills introduced during the problem solving course, specifically evaluating the usefulness and impact of the acquired skills on various aspects of their academic life.

A qualitative analysis of responses from 150 students who answered an optional open-ended question revealed a few common items that were influenced by the course. The collection of these items can be found in Table VI. Note that the total in table VI is greater than 150 as some participants responded to multiple categories. Students reported that the course was useful in influencing their work and internships the most. Their knowledge of practical skills and participation were influenced by the course.

TABLE VI
INFLUENCE OF PRACTICAL SKILLS LEARNED IN COURSE

Influence	Keywords	Total
Course/Work	class; course; work; internship; interview;	82 (55%)
Projects	project; projects;	36 (24%)
Practical Skills	git; Python; research; CFT; Wireshark; hackathon;	57 (38%)

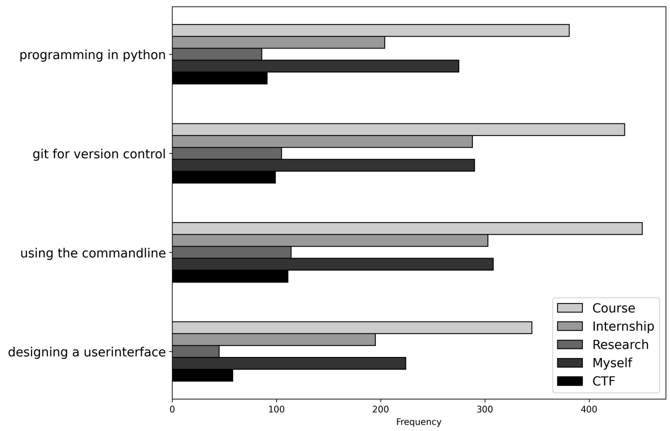

Fig. 2. Where practical skills are being used by students

To further investigate the impact of practical skills on students' academic growth and career preparations, students were asked to reflect on the use of the practical skills from the problem solving course in other settings. Four of the practical skills taught in the course are shown in Fig. 2. Students were asked where they had utilized these skills in the past three years. There is a common occurrence of the practical skills being used in the students' coursework. The use of skills were also being used in internship and personal settings. Capture the Flag (CFT) and research are the least used places for practical skills. Fig. 3 illustrates the comfort levels reported by students immediately after the course and in their senior year. Personal programming projects continue to be rated as the highest comfort level. On average, students reported increased comfort levels in all co-curricular activities, except for Capture the Flag, which is not involved in any other required CS courses. This suggests ongoing engagement in practical skills, even if students have forgotten the perceived helpfulness of the course.

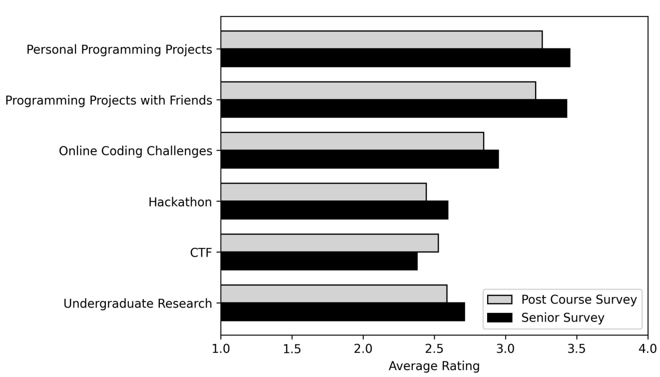

Fig. 3. Comfort with practical skills compared across years.

We further compared students' responses to the six questions asked in the post-course by the same questions in the senior-year data as shown in Fig. 4. Reflections on the course indicated that some students felt it lacked depth on topics or that they had forgotten about the content. Despite being designed as an introduction to various practical skills, students'

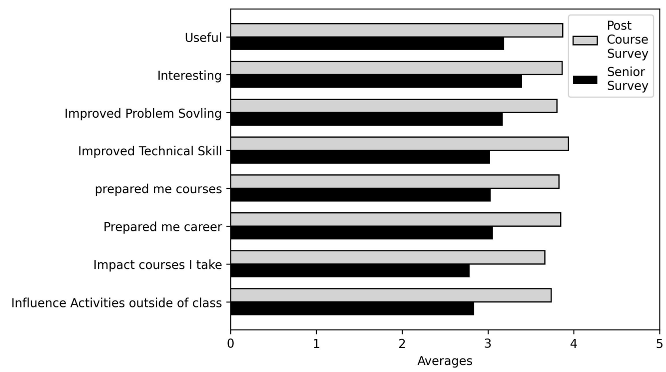

Fig. 4. Change in perception of course value across the years.

responses suggest the course was not helpful. However, the course could have grounded many of the topics introduced, allowing students to learn more in-depth in future courses or projects. In summary, students' opinions about the course have dropped negatively since they took the survey immediately after. This could be the result of students' forgetting the importance of first-time exposure to practical skills.

C. Longitudinal Study- RQ3

From the students who completed these surveys, we were able to track 68 of those students between the two surveys by matching their response ID. This would allow us to answer our third research question which is: *Does the perception of undergraduate computer science students about early exposure to practical skills change as they progress through their degree?*

These 68 students reflect similar perceptions of practical skills as the large collections of student responses. Table VII shows the demographic of these students. The survey data presents gender in relative proportion to the total data, but it lacks representation from underrepresented groups. These 68 students reflected similar comfort levels as Fig. 3 for the 957 and 512 students. The result of a t-test on 66 of the students who answered the comfort level is in Table VIII.

TABLE VII
STUDENTS SURVEY RESPONDENTS DISTRIBUTION

Gender	Male	49 (72%)
	Female	18 (26%)
	Other/NR*	1 (<2%)
Race	White	38 (56%)
	Asian	27 (40%)
	URM‡	1 (<2%)
	NR*	2 (<3%)
Total		68 (100%)

*NR: Not Reported; ‡ URM: Underrepresented Minorities

Two of the students chose not to answer this part of the survey but were kept in the 68 students because of their insights. The t-test shows that there was only a significant difference in the comfort levels of the 66 students in the personal projects and programming projects with friends. There were particularly six students out of the 68 that provided deeper

TABLE VIII
STUDENT COMFORT LEVEL FOR 68 STUDENTS

	Post-Course	Senior-Seminar	*p-value*
Personal projects	3.27	3.57	**.021**
Programming projects	3.1	3.5	**.003**
Online coding challenges	2.85	2.99	.327
Hackathon	2.5	2.67	.26
CTF	2458	2.41	.78
Undergraduate research	2.74	2.90	.34

insight into these students' perception of practical skills. The sample responses from these eight students are in Table IX.

TABLE IX
SAMPLE STUDENT PERCEPTION- POST-COURSE SURVEY VS SENIOR-YEAR SURVEY COMPARISON RESPONSES

Student 1	
Post-Course	I learned a lot about web development and python applications and seeing how accessible the tools are, I will probably use some of what I learned in the second half of this course in personal projects.
Senior-Year	There were some interesting concepts that I learned which inspired me to work on personal projects outside of school or helped my understanding of internship related work.
Student 2	
Post-Course	I was exposed to topics that I might pursue in the future
Senior-Year	I first learned backend/NodeJS/Express in this course, and shortly after I got involved in an undergrad research project where I made a full stack app with NodeJS and Express. I didn't seek out that project specifically because of the course, but it helped me be a little more prepared for learning backend for that project.
Student 3	
Post-Course	The class introduced me to Python which is a much easier language to produce fun interesting projects on my own.
Senior-Year	This course was my introduction to Python, and pretty much everything I do now after that class as a personal project is in Python. I absolutely love the language
Student 4	
Post-Course	I know more about different fields of computer science from this course and that helps me tremendously.
Senior-Year	After learning node.js in this course, I replicated the server from in class in my hackathon, which helped us win runner-up.
Student 5	
Post-Course	The different skills I learned in this class were highly interesting to work on, however, I wish I had more time to learn each of the skills so I could further increase the interest on that particular subject. I think with this, I will choose my classes based on what I am interested in.
Senior-Year	This course was when I got to learn more about cyber security and we did a CTF in that class. Every since then, I have been motivated to attend various challenges that deal with puzzles and cyber security skills.
Student 6	
Post-Course	I plan on creating a web app for a personal project to talk about in interviews and I plan on using a lot of skills and techniques I learned in this class.
Senior-Year	I was able to get basic knowledge about topics I had little to no experience in which lead me to expand upon that knowledge through personal projects which I discussed in many interviews.

Student 1 displays a belief early in their exposure to practical skills that it will be helpful for their personal projects. Three years later the same student reflects on the introduction to practical skills as something that not only inspired their personal projects but also helped with their internship. Student 2 mentions in the post-survey pursuing the skills learned from the course in the future. During the senior seminar, they reflected on the numerous skills learned and how they helped their research. The early exposure to practical skills helped with their future projects. Student 3 expresses an interest in Python after taking the course. After three years the student is enthusiastic towards Python. They absolutely love the language that was introduced during the course. Students 4 shows similar experiences as student 3. They expressed the usefulness of the practical skills introduced in the course. The students would then use the knowledge in their future projects. This shows that students are using the practical skills. At first, student 5 felt that there was not enough time to fully develop an interest in a particular subject. However, during the senior-year survey, the student mentioned that the course inspired them to start attending challenges related to cyber security. This shows that the student had developed an appreciation during the course. Student 6 displays a desire to create personal projects from the knowledge learned from the course. They wanted to use the skills from the course to engage in their projects and interviews. In their senior-year survey, they mention their initial goals and how their skills developed over the years.

V. DISCUSSION

In this work, we analyzed survey data collected in a study, with the goal of better understanding the perception of students. Our findings show that the perception of early exposure to practical skills changes as they progress towards the completion of their degrees. Initially, the majority of the students recognized the importance of practical skills by indicating the usefulness of these skills and that the skills would enhance their futures. However, the senior-year survey revealed a decline in perceived usefulness, indicating a change in perception over the three years. This shift could be caused by students forgetting the importance of early exposure to practical skills.

Motivational impacts appear significant from the results. The qualitative analysis of responses highlighted students' enjoyment and interest in activities outside of coursework. This emphasizes the importance of introducing practical skills in fostering engagement in co-curricular activities. The results show a positive influence on students' comfort with co-curricular activities and their futures.

The longitudinal analysis revealed insights into how students compare the course's influence over time. While students initially responded positively about the course and its practical skills, the senior-year survey indicated a decline in perceived usefulness. However, despite this decline, students reported increased comfort levels in most co-curricular activities over the three years, suggesting ongoing engagement in practical skills even if students have forgotten the immediate impact of the course. Additionally, the individual student reflections provided deeper insights into the long-term benefits of early exposure to practical skills, with many attributing their success in future projects and internships to the skills acquired during the course.

VI. Conclusion

This study highlights the importance of early exposure to practical skills in enhancing students' motivation, interest and impact on future careers. While the students found the course less useful after three years, the observed enjoyment and usefulness of these skills among students shows the importance of learning practical skills early in the curriculum.

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