WIP: Evolution of a Networking Course - Attitude Changes a Decade and a Pandemic Later

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***Abstract*—This work in progress research paper describes the findings of an anonymous survey modeled after the persistence in engineering survey instrument that we conducted a decade apart in 2014 and 2024. Significant changes in the mid-2010s to the mid-2020s have altered course delivery and resulting student perceptions, and we find statistically significant differences for program persistence, student self-perceived performance, perceived course value, course enjoyment, self-perceived learning gains, and self-perceived learning material engagement efforts. Interestingly, we did not find significant differences between the two groups with respect to self-reported time spent on different course activities or general student population characteristics, such as self-reported credits, GPA, work hours, or commutes. When considering the averaged changes, we note that students in the more recent blended and virtualized environments exhibit a higher level of persistence than their peers. This showcases the overall increase of blended and decentralized/virtualized instruction having a positive impact on student attitudes based on the feedback collected.**

***Index Terms*—Student attitudes, Computer science education, Blended learning**

I. Introduction and Motivation

In this work in progress research paper, we compare changes in student attitudes for an evolving course in introductory networking between 2014 and 2024. This decade saw significant changes in the approaches to instruction, learning, and the delivery of educational content. Some examples of these changes include the broad emergence of electronic textbooks and a greater reliance on online learning. Although some developments were driven in part by coronavirus pandemic measures in the early 2020s (see, e.g., [1], [2]) most were general trends that were already underway [3]. These measures included an initial transition to remote and fully online instruction in 2020. Subsequently, the instruction commonly continued in a HyFlex fashion [4] for 2021 and 2022 before switching back to regular face-to-face in 2023. The switch back to a regular, albeit often modified, instructional format has also provided some benefits and challenges, and stakeholders are eager to use lessons learned from emergency pivots earlier in the decade, such as described in [5], [6].

We regard the types of course modifications we consider in this paper commonplace, as they reflect ongoing shifts to blended learning in the computer science and engineering domains as outlined above. We did not find a significant body of research that investigates how student attitudes in communication networking courses have changed alongside these general trends. Most of the research to date has focused on the integration of networking into the instruction and peer interaction domains, with Metaverse applications as the latest embodiment; see, e.g., [7], [8].

Blended learning [9] in higher education [10], [11], [12] has made global advances for all types of learners [13], [14]. A common trend is the integration of local and remote instructional efforts resulting in challenges of learner integration, especially for synchronous course components. Components such as virtual labs have been incorporated in a number of disciplines [15], [16], [17], [18], [19], including Computer Science [20]. As a recurrent theme, these and other studies commonly find more positive student attitudes as a result of incorporating virtual labs into blended instruction.

Although novelty could initially be attributed towards positive results, after the pandemic, novelty typically no longer applies as learners in general were forced to pivot to utilize some form of remote hands-on course components. Studies have emerged that investigate some of the performance and motivation issues between these time periods [16], [17]. New strategies for blended learning are emerging on the basis of lessons learned in recent years [21]. Evaluations of student attitudes are often limited to technological aspects [22] while the pandemic added an additional shift to self-regulation. Attitudinal aspects become increasingly important as self-regulation of learners for blended learning components becomes increasingly a requirement [23], [24].

To guide future developments in communication network education, additional insights are needed that consider how students perceive the pivotal changes that occurred in recent years. This paper addresses this current lack in networking education literature by comparing students' attitudes in an introductory networking course in an information technology program that focuses on hands-on instruction. We compare student responses from 2014 and 2024 to provide insights into the impacts from moving from a dedicated traditional and dedicated setting to a decentralized semivirtual ad hoc learning environment. In the remainder of this work-in-progress, we provide the initial background of the course and its evolution, as well as the survey we used to gather student feedback. We

subsequently present and discuss the results to inform future research and possible course modifications based on student feedback.

II. Implementation

A. About the Course

The course under consideration is a mandatory introductory course to networking in the undergraduate major in Information Technology with a hands-on focus. The course is loosely designed to fulfill the main criteria of the joint Information Technology Curricula 2008 (IT2008) and 2017 (IT2017) by the Association for Computing Machinery (ACM) and the IEEE Computer Society (IEEE-CS) [25]. Specifically, the course aims to introduce second-year students to telecommunications network standards, components, and requirements while developing hands-on skills for initial competency. After successful completion of the course, students should also be able to analyze and compare the characteristics of standard communications protocols and evaluate application requirements and telecommunications solutions.

For a more competency-based evaluation of student outcomes, the course also targets a basic design and implementation of a simple networked application, student familiarity with command-line and/or graphical utilities for network evaluations and/or troubleshooting, and an ability to perform basic high-level network planning and administration. These desired course outcomes are mapped to the IT2008 and IT2017 performance items as guidelines and for assessment. The course was also aligned with some of the common requirements for the Computing Technology Industry Association (CompTIA) Network+ certification to provide students with initial preparation should they wish to take the certification exam in the future.

B. Course Evolution

We highlight the general evolution of the course in Figure 1 showcasing the major change from a traditional centralized lab-based class composition (traditional textbook, lecture with slides, hands-on lab units, and different assignments) to the blended decentralized format (electronic integrated textbook, few lectures with high-level slides, virtual labs, and fewer/smaller assignments complementing the exercises in the textbook). The initial course offerings combined a traditional textbook [26] (and newer editions) with significant supplemental material, especially for additional hands-on exercises. These exercises were carried out at the Department of Computer Science's Central Advanced Network Architecture Laboratory (CANAL). CANAL was designed for hands-on active learning with dedicated workstations and Cisco, Inc. switches and routers.

During the coronavirus pandemic, the instructional mode changed to home instruction. Although initially the original textbook was maintained, some issues became apparent for its use together with the supplementary materials. For a lower-level undergraduate course delivered in an online setting, too much additional setup and configuration work was required to maintain the same content as prior to the pandemic.

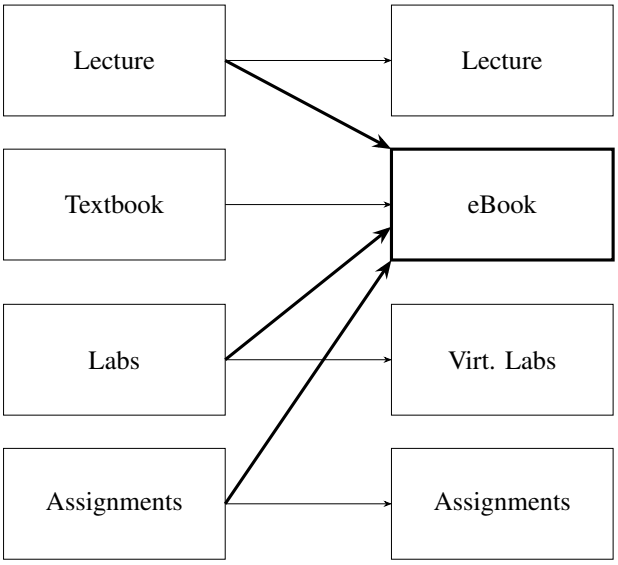

Fig. 1: Overview of the course evolution from 2014 to 2024: most content was moved to the integrated electronic textbook, which contained narratives, videos, and cloud-based hands-on laboratory units.

The return to partial in-person instruction coincided with the department's loss of the CANAL environment and with the ability for hands-on instruction that considers all the required content for the course. In turn, the textbook was changed to an integrated online textbook focusing on Network+ Certification [27]. The interactive online textbook also included a significant amount of hands-on lab exercises that simulate the environment used before in CANAL, and more. In 2022, the course was delivered in HyFlex format [4] and the online text was supplemented with homework questions and a network application programming assignment. The programming assignment used graphical programming and was designed to allow students to use general purpose on-campus computers, their own personal computers, or remote desktop environments (due to the HyFlex instructional mode).

Starting in 2023, the course switched back to an in-person instructional mode and made ad hoc use of general purpose computerized classrooms for active learning entailing guided experimentation beyond the electronic textbook. These hands-on assignments employed a virtual environment that was able to be executed on the university's remote desktop environment and on computers in general-purpose computerized classrooms. This approach was continued in 2024 and represents the current state of the course.

C. Survey and Survey Administration

Students were asked in both years (2014 and 2024) to complete the anonymous survey just shortly before the middle of the semester. This equates to approximately the same time, but with different content coverage as outlined in SectionII-B. We modeled our survey after the Persistence in Engineering (PIE)

survey instrument [28]. We used other iterations successfully in other works, such as [withheld for blind review]. In the original version of the survey used in 2014, the questions were presented on a custom-created single continuous web page. In 2024, the survey was generated using the Qualtrics survey software. In each of the two years the survey was presented to students online and was accessible for several days using any modern web browser. The students were informed about the survey through emails and announcements in the course's Learning Management System, including the voluntary and anonymous nature of the survey.

III. Results

We provide a selection of the results obtained through surveys from students enrolled in the networking course in Spring 2014 (n=8) and Spring 2024 (n=9) in Table I. These represent the return rates of 29% and 33%, respectively. Due to the relatively small sample sizes, throughout our comparative evaluation, we consider independent sample t-tests for comparison of the answers for different years, with Levene's test for equality of variances [29].

We initially note that the averaged means between the two cohorts are statistically significantly different. The 2024 students had a higher overall level of agreement with the survey statements ($M = 4.09, SD = 0.27$) than their 2014 counterparts ($M = 3.69, SD = 0.28$), $[t(15) = 2.975, p = 0.009]$. We next highlight commonalities and differences.

A. Participating Student Populations

Due to the early placement of the course in the curricular offerings of the programs described in Section II-A at a university in the Great Lakes region of the U.S., students enrolled in the course in 2024 had their higher education learning experience either during the pandemic or in a post-pandemic setting. For the sake of brevity, we do not include the characteristics self-reported by the survey respondents in Table I. The participating student populations had slightly different age levels ($2014: M = 24.6, SD = 11.5; 2024: M = 20.8, SD = 1.6$) which, however, were not statistically significant. The overall self-reported GPA was similarly not found to be significantly different ($2014: M = 3.3, SD = 0.5; 2024: M = 3.3, SD = 0.6$).

Considering self-reported credit hour enrollment, the respondent populations also did not show a significant difference ($2014: M = 13.3, SD = 1.5; 2024: M = 15.3, SD = 5.3$). When asked about hours worked outside of enrolled course credits, students answered at different levels overall, though they were not found to be statistically different ($2014: M = 9.1, SD = 8.8; 2024: M = 5.7, SD = 7.7$). We also evaluated the self-reported distance students commute to campus ($2014: M = 2.8, SD = 3.6; 2024: M = 5.3, SD = 10.8$) – again without statistically significant differences between groups. In general, we can therefore regard the survey respondents as generally comparable student populations with respect to these basic characteristics.

B. Significant Differences Between Years

The overall long-term persistence in major course offerings was captured by asking students if they wanted to continue taking courses in the related majors. This survey item exhibits a significant difference between the 2014 ($M = 4.13, SD = 0.84$) and the 2024 ($M = 5.0, SD = 0.0$) cohorts, $[t(7) = 2.966, p = 0.021]$ with the 95% confidence interval of the difference between means ranging from 0.177 to 1.573. Levene's test indicated unequal variances ($F = 19.137, p =< .001$), so degrees of freedom were adjusted from 15 to 7. All respondents in 2024 agreed that they want to continue taking courses in comparison to their peers a decade ago.

The anticipated persistence also correlates with self-perceived performance ("I think that I am doing well in this course."). In 2014, students rated their agreement just slightly above neutral ($M = 3.25, SD = 0.89$), indicating that they assumed their performance to be just average. In 2024, however, responding students mainly agreed with the statement ($M = 4.22, SD = 0.44$), $[t(15) = 2.917, p = 0.011]$.

The difference between the two cohorts continues with the valuation of the course as worthwhile. The respondents in 2014 ($M = 3.75, SD = 0.89$) valued the course less than their peers a decade later in 2024 ($M = 4.67, SD = 0.50$), $[t(15) = 2.668, p = 0.018]$. Students also had different views on how enjoyable their course experience is (we note again that the survey was posted mid-semester), with students in 2014 rating their experience lower ($M = 3.00, SD = 0.93$) than students a decade later ($M = 4.22, SD = 0.67$), $[t(15) = 3.151, p = 0.007]$. For self-perceived learning, a significant difference can be observed for feedback obtained in 2014 ($M = 3.63, SD = 0.74$) and 2024 ($M = 4.56, SD = 0.53$), $[t(15) = 3.004, p = 0.009]$.

Although other differences can be observed at a generally higher level in 2024 than in 2014, they were not found to be statistically significant and therefore can only be regarded anecdotally.

IV. Discussion

The first somewhat counter-intuitive (as an instructor) finding is that, on overall average, students in the blended/decentralized/virtual 2024 course iteration seem to have higher satisfaction with their educational endeavor than those in 2014, which were exclusively based on face-to-face and directly guided laboratory interactions. However, intermediate experiences and increasing self-regulation skills (and demands) seem to favor a more flexible instructional environment, outweighing the former more scheduled instructional approach.

A. Student Background

While no significant changes were discovered for the student groups making them comparable, there could be an underlying trend indicating that students might take more credits and live farther away from campus but work less hours, thus replacing work hours with credit hours. As we intend to survey students

TABLE I: Survey results for 2nd year undergraduate networking course in the information technology program for years 2014 and 2024 (Likert-type scale from 5-Strongly Agree to 1-Strongly Disagree). Items with statistically significant differences are marked with *.

	2014 (N=8)		**2024 (N=9)**	
	Mean	Std. Dev.	Mean	Std. Dev.
I want to continue taking computer science (CS) or information technology (IT) courses.*	4.13	0.84	5.00	0.00
After graduation I want to become a computer scientist/IT professional.	4.25	0.71	4.56	0.53
I think that I am doing well in this course.*	3.25	0.89	4.22	0.44
I have good math skills.	3.50	0.93	3.78	0.67
I have good science knowledge.	3.63	0.74	3.44	1.24
I am good at applying math and science to real-world problems.	3.75	0.89	3.22	0.67
I like working in teams.	3.25	0.71	3.56	0.88
I perform well on teams.	3.75	0.46	4.00	0.87
Creative thinking is one of my strengths.	4.13	0.64	4.11	0.78
I am skilled at solving problems that can have multiple solutions.	3.75	0.89	3.89	0.60
Math skills are important for computer scientists and IT professionals.	3.75	1.04	4.00	1.23
Science knowledge is important for computer scientists and IT professionals.	3.63	0.92	3.89	1.05
An ability to apply math and science principles to real-world problems is important for computer scientists and IT professionals.	3.88	0.99	4.56	0.73
An ability to perform on teams is important for computer scientists and IT professionals.	4.25	0.71	4.78	0.44
I feel stressed about the course load for this class.	3.25	1.04	3.56	0.88
This is a worthwhile course.*	3.75	0.89	4.67	0.50
This is an enjoyable course.*	3.00	0.93	4.22	0.67
I think that I am learning a lot in this course.*	3.63	0.74	4.56	0.53
I think that learning the materials for the online textbook (2014: the lecture) requires a lot of effort.	3.75	0.89	4.44	0.73
Keeping up with course readings is difficult.	3.63	0.92	3.33	1.23
Average*	3.69	0.28	4.09	0.27

in future course iterations, we are interested in confirming this trend.

B. Persistence

The initial survey question immediately showcases the difference between cohorts, which remains a general theme throughout. Responding students in 2024 are significantly more eager to continue taking courses in the domain than in 2014. Although we did not explicitly ask, reasons could be that students that are enrolled in the major a decade after the first cohort have had a significantly higher level of engagement with information technology throughout their high-school and early college experience due to blended instruction pivots as part of the pandemic mitigation efforts. In turn, responding students in 2024 likely have already identified their long-term career, while more students in 2014 were still unsure about their long-term prospects in the domain.

C. Self-Confidence

Averaging the observations for "I think I am doing well [...]" and "I think that I am learning a lot [...]", we derive a statistically significant difference between the 2014 ($M = 3.44, SD = 0.56$) and 2024 ($M = 4.39, SD = 0.42$) groups, $[t(15) = 4, p = 0.001]$. This indicates that the evolved course offering provides a better environment to foster student perception and likely also reinforces their career choice, as indicated by their persistence.

D. Collegiate Experience Satisfaction

Similarly averaging to deduct the overall satisfaction with the collegiate experience, we use the "[...] worthwhile course" and "[...] enjoyable course" survey items. Again, students in 2024 ($M = 4.44, SD = 0.53$) indicated a significantly higher level of satisfaction than their 2014 counterparts ($M = 3.38, SD = 0.84$), $[t(15) = 3.2, p = 0.006]$. We postulate that the blended format provided students in 2024 with the means of self-regulation that they were getting accustomed to during the previous years. As such, the blended learning course format combining different instructional means and the ability to perform labs in a decentralized at-home fashion aided in the flexibility students have come to expect.

V. Conclusion

Conclusions that can be drawn from this are that (i) the new generation of learners have now successfully embraced the means of decentralized and virtual hands-on exercises that enable active learning, (ii) moving the textbook to an integrated online textbook that includes active learning elements increases the perceived effort, but does not decrease motivation, and (iii) self-perceived performance and persistence have increased with the availability of virtualized hands-on course elements that enable anytime, anywhere engagement and flexible student course participation based on individual needs.

Overall, these results are in line with recent literature on empowerment and a move toward self-directed and differentiated instruction, which guides this course's next evolutionary development. Similarly, these findings also indicate that the current trends of self-regulation research are well warranted and we intend to evaluate the studend efforts in this regard in the future. Sepcifically, we intend to use these findings in the refinements of the course and the content materials used and repeat the survey in regular intervals to determine how the continuous course evolution impacts future student attitudes.

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