Making the connection: Encouraging technology-specific reading skills through structured readings of texts

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Abstract

Over the past decade, we, as a society, have been growing accustomed to consuming bite-sized chunks of information. It is delivered to us over mobile devices with considerably smaller viewing screens than even laptop systems. Communication often takes the form of text messages, and social media feeds. For high-school students transitioning to engineering technology-related programs, these forms of communication are the norm. The thought then of wading through actual textbooks, particularly in engineering- or technology-related ones can be rather challenging. It is particularly so for students who may be underprepared for the fairly intensive technical reading required in addition to their science, math, and computing classes. These are essential skills for success in the 21st-century technology workforce. Alongside these, students need to learn how to adequately prepare students to read textbooks, technical documentation, whitepapers, conference proceeding, and journal papers related to their major. Given the fast pace of technological changes, graduates are likely to be doing much reading. The reading may be in the form of specification sheets, comparing system functionality, or reports while tracking down connections between specific pieces of information in a sea of data. It is the active reading of technical texts that is the focus of this paper and presentation. We promote its development using structured readings from the textbook, along with various in-class activities requiring students to actively use online search tools and summarize the information both verbally and visually. Note-taking in engineering and technology-related disciplines often includes numerous equations, detailed calculations, and diagrams. The use of graphical illustrations and icons magnifies the impact of the annotation. It results in visual consolidation of content, allowing immediate access to both the zoomed-in view of the topic, as well as potentially a pull-back view. With connections to autonomy, relatedness, and competency, purposeful reading engaged through the annotation process can motivate students to recognize themselves as future technologists.

Students in a computer networking hardware class are made aware of various reading strategies they can use while reading technical texts. The Metacognitive Awareness of Reading Strategies Inventory (MARSI) is a self-reported survey of how people read textbooks and other academic materials. It can be used for students to assess how they are progressing as readers in their discipline-specific texts. Students indicated a preference for re-reading difficult technical content and the use of graphical elements such as tables, graphs, illustrations as a way for increasing their comprehension of the content.

Keywords

Technical documentation, purposeful reading, critical thinking and reading, annotation, visuals with words

Introduction

Engineering and technology students require reading skills for effectively summarizing technical information and transforming it into actionable form. Students can sharpen reading skills with practice under increasingly complex conditions. In the 2019 National Survey of Student Engagement (NSSE) [1] of four-year colleges and first-year university students, 54% percent

noted that there were some to no assignments that required them to summarize the materials they read, such as articles books, or online publications. In response to the question (1e) about whether they had "Analyzed or evaluated something you read, researched, or observed," 38% noted to have some or fewer such assignments. Requiring students to read with understanding and for a future application requires them to act with or on that information. The technology classroom is rich is such opportunities. Owing to the rapidly changing landscape we have been for the past few decades, along with the nearly exponential growth in web-based technologies, reading of print material has reduced significantly. By the time a cutting-edge technology book appears in print, the technology has likely advanced further. Faculty members teaching technology-related courses need to continually update their text and reference materials for ensuring students have access to the latest information. It is only part of the technical reading puzzle. Another part includes having students complete the assigned readings from the textbook.

Carney et al. [2] assessed the effect of three different assessment strategies on reading compliance as part of an attempt to encourage the reading of the text. It included a mix of designated and random quizzes drawn from the readings to assess students' more in-depth level processing of course material. Also included were two adaptations: one which allowed the use of self-developed notes for use on the quiz, and the other, a learning log in which responses to all quiz questions had to be submitted. A roll of the dice determines whether to grade the quiz. It also determines which of the questions to grade. While all of the methods motivated students to complete the readings, the final method motivated students the most.

According to Ryan & Deci [3], developers of Self Determination Theory (SDT), motivation is the central concern of people for the different things we do. SDT provides a framework for understanding intrinsic and extrinsic sources of motivation. In the context of engineering or technology students, it could relate to their decision about whether to choose or continue in a specific discipline and the course itself. SDT posits that the highest forms of motivation, as demonstrated through persistence, creative output, and significantly improved performance, occur when the individual's experiential conditions support it. It includes autonomy regarding the choices we can make; competence as demonstrated through actions taken with deeper understanding; and relatedness to other individuals or groups.

In proposing the Interactive, Constructive, Active, and Passive (ICAP) framework [4] predict that as students engage more meaningfully with the learning materials in each of these modes of engagement behaviors, their learning also increases. According to their classification of observed engagement behaviors in the Passive, Active, Constructive, or Interactive modes. In the Passive mode, the learner receives information (listens to a lecture, watches a video, or reads a text without taking notes). In contrast, in the Active mode, the learner manipulates it (repeats or rehearses mechanically). In the Constructive mode, the learner generates new products (going beyond the original using inferences, analogies, justifying steps, explaining, paraphrasing, comparing, predicting, reflecting, monitoring one's understanding, inducing hypothesis, posing questions, adding visuals). Finally, in the Interactive mode, multiple constructive dialogues occur between learning partners with each contributing meaningfully (taking different positions, requiring justification regarding statements, raising questions and answering them, explaining and elaborating on each other's comments). Michaelson [5] notes that instruction on critical

reading emphasizes the feelings, intuitions, and creative responses that students experience as they read.

The Metacognitive Awareness of Reading Strategies Inventory (MARSI) [6] is a 30-item instrument for assessing the perceived use of strategies while reading academic materials. Each item is self-assessed on a 5-point scale. A self-reported scale of 1 designating one never or almost never uses the strategy; a 2 that is used only occasionally; a 3 that it is used sometimes; a 4 that it is usually used; and a 5 that it is always or almost always used. The MARSI includes strategy sub-scales or factors for global reading (generalized skills such as having a purpose for the reading, scanning), problem-solving (localized or focused strategies, such as re-reading or checking ones understanding for resolving inconsistent information), and support reading (such as accessing reference sources).

An alternative to [6], is the Metacognitive Awareness Inventory (MAI) scale developed by [7]. It has been used by [8] for assessing the baseline of students' metacognitive skills in a Foundations in Engineering program, helping them construct meaningful knowledge and skills. The MAI is a 52-item self-reported instrument to measure metacognitive awareness of adults. It includes subcategories organized under the person's knowledge and regulation of cognition. Continuous values on a 100-point scale are used instead of a 5-point Likert scale for providing better approximations and for improving its reliability.

Course Information and Instructional Strategies for Promoting Active Interactions
Network Switches & Routers, NET 343, at Eastern Kentucky University (EKU) is a required course in the undergraduate degree programs related to Computer Electronics as part of the AAS Technology degree, and to Cyber Systems Technology as part of the BS degree. Students take it typically in their sophomore year. This lecture and laboratory-based course require students to configure, manage, secure, test, and troubleshoot computer network devices. There are two 2-hour meetings per week. Laboratory equipment, primarily Cisco switches and routers, determine the class size. It has ten workstations and associated network device racks, with students typically forming sub-groups of two per workstation. Through structured readings in the textbook, students learn about core Ethernet networking models, protocols, and IP network addressing. Additionally, the course includes network device configuration using the text-based Command Line Interface (CLI), securing devices using Access Control Lists (ACLs), use of Virtual Local Area Networks (VLANs), and special topics such as Network Address Translation (NAT) and multimedia communications over the network.

Every class meeting includes in-class worksheets requiring students to use their online and texts for responding to questions. Students receive and work on the worksheet individually before formal instruction on it. It is a way to spark interest in the topic and for connecting it with activities students have been completing in class. Students also develop written labs, communicating key terms, procedures, and summarizing their learning by referring to the objectives and the readings. Students use network simulation software and physical lab activities to improve linkages between theory and practice. To make learning more meaningful, the class uses various active-learning techniques. These require students to work both individually and in small groups for answering questions and cross-checking their work. Students solve design problems regarding networks, sketching, and updating their network diagrams with annotations,

adding verbal clues along with visual ones. It has helped embed the information more thoroughly. The final exam includes a hands-on group activity requiring students to set up an end-to-end network connection spanning multiple devices, ensure that it is working, and then selectively allow and block network traffic from accessing a given server.

Students enjoy the opportunity to set up their favorite types of network servers, sometimes gaming servers, and access it in an actual laboratory, then allow and block clients from connecting to it using specific security techniques. Students also maintain a portfolio in which they keep all course-related content. A well-organized portfolio is immensely helpful during the laboratory and especially during the final hands-on assessment. Student portfolios include a Table of Contents (TOC), which allows for scanning of the contents. Developing this for their portfolio is in many ways, similar to the TOC used by their textbook.

Students are made aware of specific strategies included in the MARSI [6]. Awareness of the techniques can strengthen reading skills. While reading Teo [9] encourages questioning underlying motivations, assumptions, and meanings typically assigned to standard texts as a way of "making the familiar strange" and of "making the strange familiar." The use of graphical annotations for interacting with the text, analyzing the information in visual ways can shed new light on ideas within a topic or discipline. By encouraging visual representations of ideas and questions, students have an additional creative outlet allowing for interaction and engagement with the text. In a way, it empowers them to co-author meaning. Students learn that by making ones thinking and feelings regarding specific readings from the text or other sources visible to oneself (and to others), they can reflect on and thus improve their learning processes. In [10], the strategic use of various graphical elements, such as symbols, color, contrast, groupings, and annotation, aid the development of a visual vocabulary about technical topics.

Clary & Wandersee [11] recommends using the Ishikawa fishbone diagram, in which the head of the fish represents the outcome of the information. The information shown in the fish skeleton is a visual organizer of technical cause-and-effects. It finds use in organizing technical information. It can be used as a reading strategy as well and for cooperatively constructing meaning, leading them to both how something happens and why allowing students to focus on the core material while learning new content.

Critical Reading and Annotations in the Computer Networking Technology Classroom

Documenting one's thoughts and feelings about the topic as one reads, rather than in a separate notebook, maintains a running record of the "conversation" one is having with the author of the textbook. Even though it may seem as if the reader is engaged in a rather one-sided conversation, the process of actively raising questions, forming associations, making predictions, suggesting applications, checking assumptions, and using different perspectives. These are things practitioners of their discipline do on a routine basis and advance the student on the path to technical competency. When students feel welcome to react not just intellectually but also emotionally (with responses of surprise, delight, doubt), they are engaged more fully with the material. Just as they would be when learning in person.

The annotation process can be used to both recognize and, if needed, create an outline of the chapter. Students investigate if this type of structure is available in other sections of the text. It

helps them read a technical document in their discipline more effectively. Now, they are learning not just for content but also for noting the structural elements being used by the author for conveying the information. The use of illustrations and examples is of particular importance, as are the introduction and end-of-chapter summaries, offering fertile starting ground for the annotation process. Students can feel that they are getting a boost in understanding. When students can raise interesting questions about the reading, and try to answer these themselves, that leads to greater confidence in their competencies about computer electronics and networking. It, in turn, helps them become more autonomous as technologists. Figure 1 shows a screen clip used while discussing readily implementable reading strategies and annotation cues.

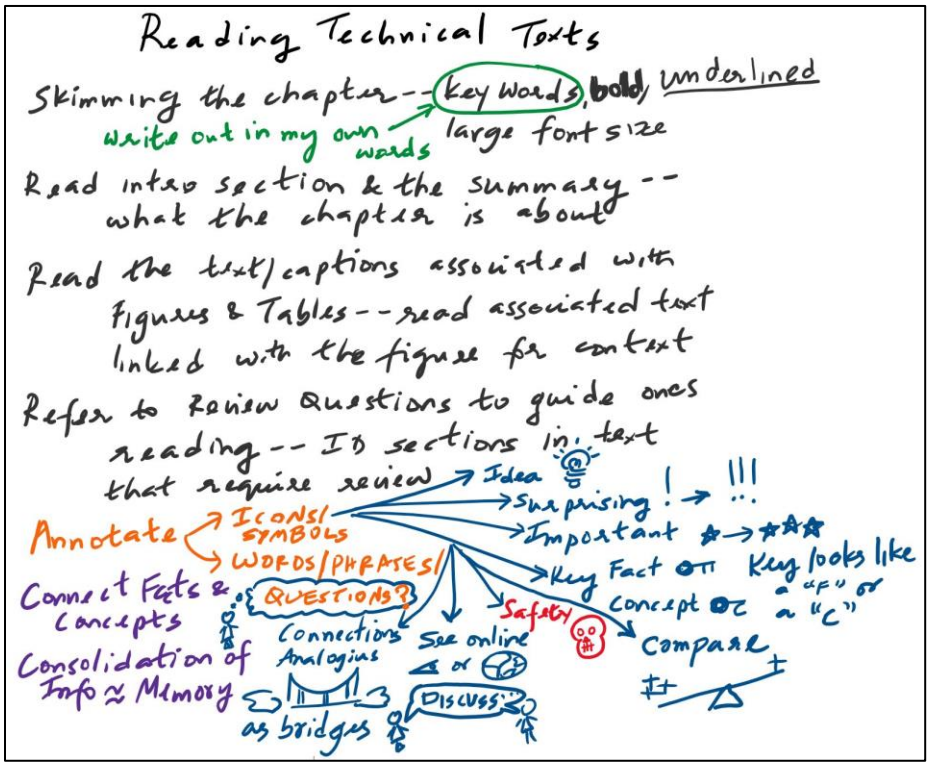


Figure 1. Highlighting easy reading strategies for students to use while reading their text, including adding annotations

By requiring students to both summarize the readings from the textbook and to connect it with laboratory or real-world experiences, students gain a deeper appreciation for the linkage between theory and workplace practices. Making technical readings a required part of the course and across the curriculum also improves engagement [1] in the major. Allowing students to identify the top three to five questions at the end of the chapter they found challenging, responding to these, and explaining how their thinking about the topics has been challenged and expanded gives students greater autonomy regarding their learning from the text. Persisting through such intellectually challenging tasks also links to higher levels of motivation that SDT [3], allowing them to regulate their learning with a better understanding of the content.

While creating annotations in their notes and the textbook, students are encouraged to connect the reading or content with a relatable experience or object. Food-based visual analogies are both highly relatable and quickly sketched. For example, while discussing the types of network

cabling required between various network devices such as routers, switches, hubs, or computer systems, the analogy of a burger, as shown in Figure 2, can be used.

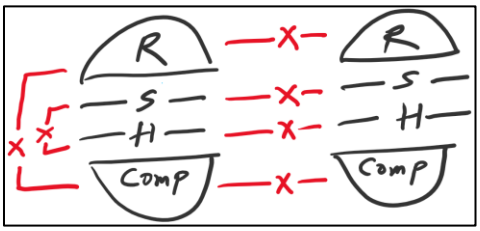


Figure 2. Ethernet cabling between network devices shown using the analogy of a burger. "R" for a router, "S" for switch, "H" for hub, "Comp" for computer, and "X" for crossover cables. Other Ethernet cables connecting networking devices are straight-through.

Connections between similar network devices (router to router, for example) require the interchange of the transmit and receive pins on the connectors at each end of the cable. We achieve this using crossover Ethernet cables. Under Ethernet cabling standards, computer systems, routers, and Access Points (APs) all transmit and receive transmissions on the same pins. Switches and hubs use the opposite pairs. So, a switch can be directly connected to a router or a computer system using a straight-through Ethernet cable. Students sketch these in their notes and texts, as well as include these on handwritten index cards.

Students who are currently working in related disciplines are finding the purposeful reading process especially useful. They can comment about the specific ways in which they are finding applications of theory in the workplace. For example, a student in a technology class noted how he had previously observed that the first half of the hardware address of a batch of Voice over IP (VoIP) phones was identical. Following up on the readings in the text, he realizes that these were Organizationally Unique Identifiers (OUIs) associated with the phone manufacturer such as Cisco, Avaya, Nortel. He was excited to share that with the class. These types of learning connections that arise from readings of the text when shared through reports and in-class discussions help other students connect theoretical concepts to practical applications. When students can make predictions about possible uses or connections of the technology they are reading about in the current readings and then further into the chapter, verify that this is indeed the case; they have successfully connected one piece of theory with another.

In-class small group activities are a vital part of the learning in the class. Worksheets require students to try to reach a consensus on the best or the most effective way to solve given technical design or troubleshooting scenarios. Actively referring to their annotated notes, text, and online resources in a group setting allow students to engage more meaningfully with the content, as suggested in [4]. It also improves their technical communication skills.

Ideas from [10] guide the visual representation of technical facts and concepts in the Network Switches & Routers course. Various graphical elements, such as lines, shapes, size, color, spacing, texture, groupings, and icons are interwoven in each lecture. It allows students to build their visual and verbal vocabulary of the technical topics under discussion. The personalized system of visuals and symbols that students create while experimenting with annotations can be immensely helpful in developing their self-confidence. They are learning about applying the

technology with understanding. It can help make the reading of other, unfamiliar technical documents easier. As students progress through the technology curriculum, structured reading tasks progressively scaffold their understanding, preparing them for the challenges of practically deploying upcoming technologies in the workplace.

To build awareness of the importance of thoughtful reading of technical texts, a portion of the class at the start of the semester was used to lead a discussion on how students are currently reading online and print materials required for their classes. Initially, students spend time thinking about how they read, listing the strategies they have found to be personally helpful. They rank order these strategies, which are then shared out in the class, with the faculty member listing and annotating these on the whiteboard. Figure 3 shows a listing of the reading strategies suggested by students in the Network Switches & Routers class. Posts in the Blackboard Learning Management Systems (LSM) include clipped photos of the whiteboard notes with annotations added in for boosting student engagement in the reading. Students thus had the opportunity to make their thinking about this critical topic visible, and at the same time, learn from the best strategies their peers are using. As noted by researchers in [6-8], awareness of metacognitive processes can help in ways of improving understanding of a topic. By deliberately discussing these and other learning strategies as part of in-class activities, students are encouraged to monitor their understanding as they read or apply it for working through technical scenarios.

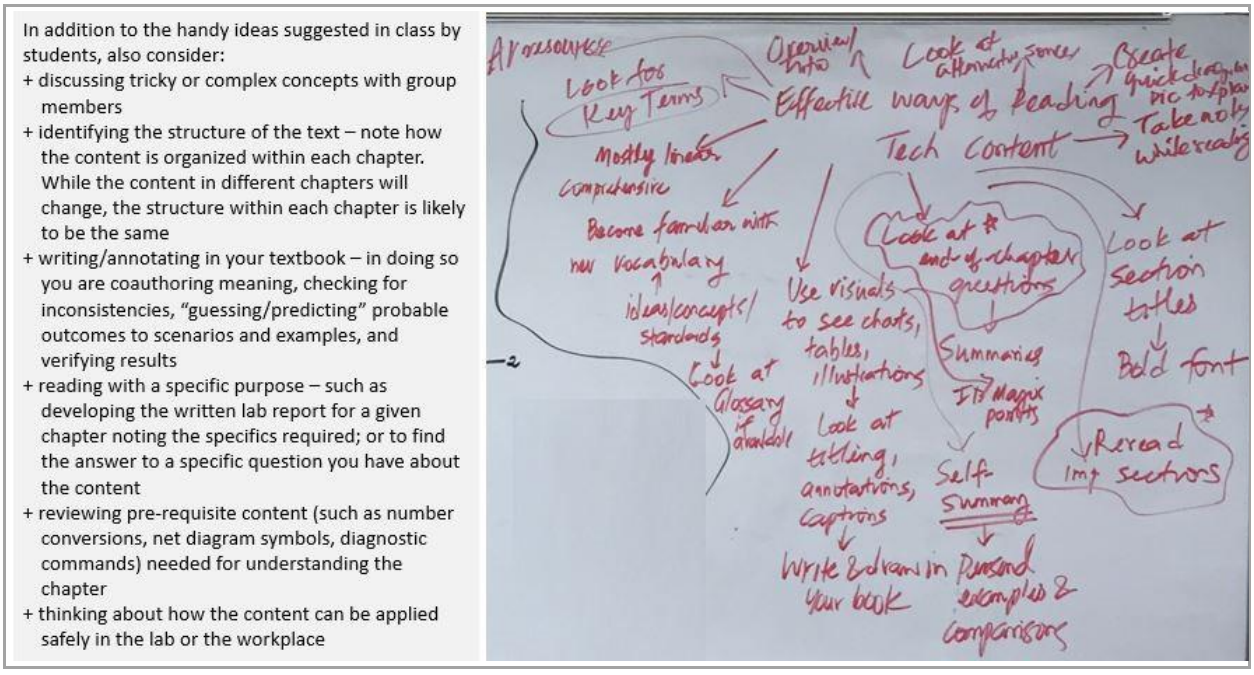


Figure 3. Student-suggested strategies for the effective reading of technical texts

Following the in-class discussions on reading strategies, students reviewed the strategies listed on the MARSI and rank-ordered the ones they prefer to use regularly. Fifteen students (n=15) in Network Switches & Routers class in Fall 2019 and eleven students (n=11) from the Spring 2020 class participated in discussions on critical reading strategies and the anonymous survey of their reading preferences. The fall class had one female, and the spring one had all male students.

Most of the students in the class are computer technology-related program majors. Students in the Computer Science and Computer Information Systems programs take this course as an elective. From the list of reading strategies, students also identified ones they would like to explore further. Table 1 shows the top three reading strategies identified by the Network Switches & Routers class in Fall 2019 and Spring 2020. Figure 4 shows the preferred generalized reading strategies, and Figure 5 the preferred problem-solving reading strategies in the Fall 2019 and Spring 2020 semesters.

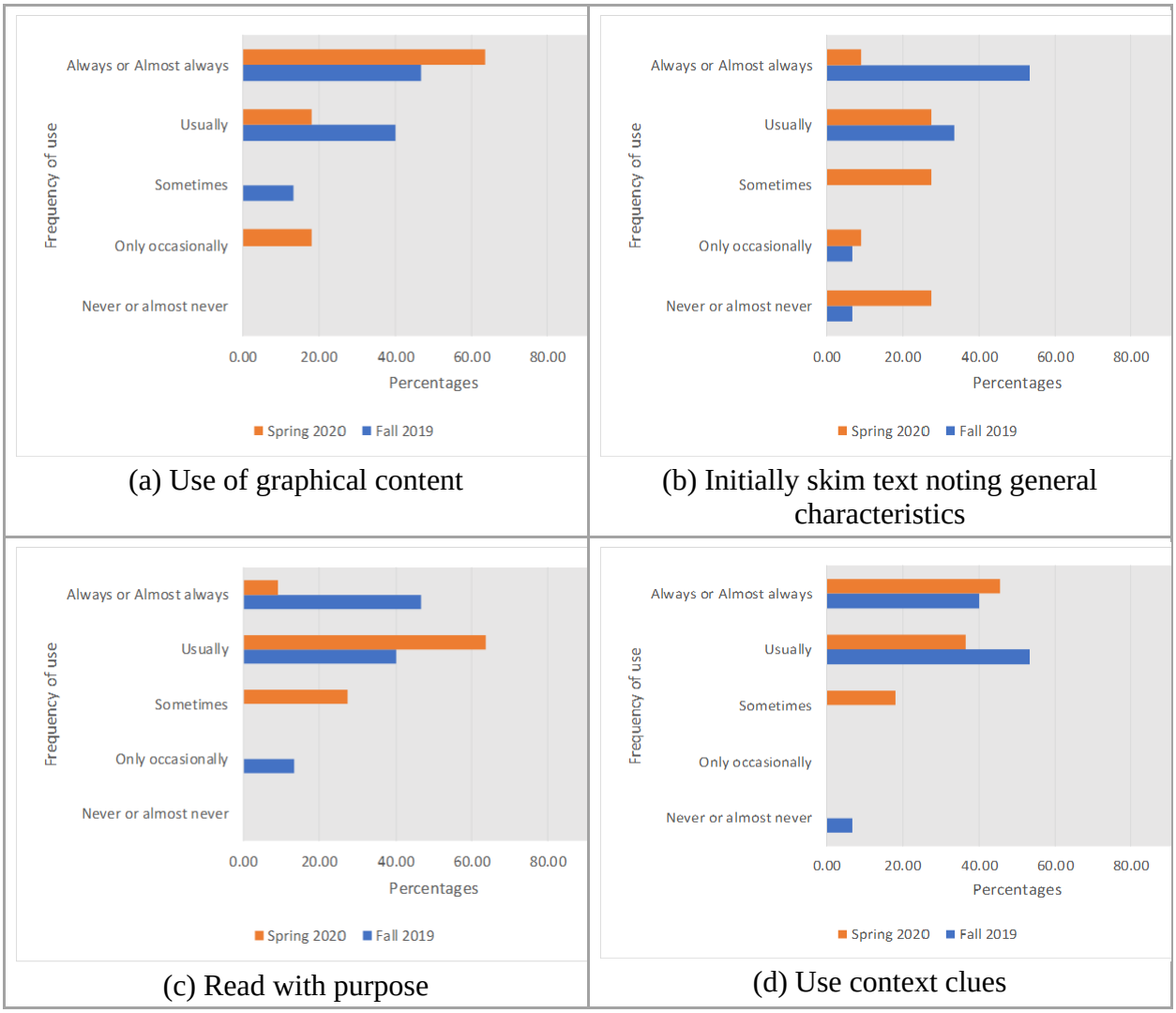
Table 1. Self-reported preferred reading strategy for increasing understanding of content. The abbreviation [PS] refers to a Problem-solving reading strategy and [G] to a Global or Generalized reading strategy as identified in [6]. Survey prompts have been reworded for clarity based on the application of reading strategies in the context of computer networking content.

	1st Preference	2nd Preference	3rd Preference
2019 Fall (n=15)	• Re-read difficult portions (66.7%) [PS]	• Read slowly and carefully (53.3%); [PS] • Initially skim text noting general characteristics [G]	• Read with purpose (46.7%); [G] • Use of graphical content [G]
2020 Spring (n=11)	• Use of graphical content (63.6%) [G]	• Adjust reading speed (54.6%); [PS] • Re-read difficult portions; [PS] • Get back on track after losing concentration [PS]	• Use context clues (45.5%); [G] • Visualize information to help remember [PS]

Students were encouraged to identify items on the Metacognitive Awareness of Reading Strategies Inventory (MARSI) instrument that they would like to try out based on the class discussions regarding the importance of critical reading in technology fields. The top choice for reading strategies to try out in both Fall 2019 and Spring 2020 was paraphrasing or restating in one's own words to better understand the content. Additionally, in the spring semester, reading with others, and reading aloud to improve understanding tied for the top spot of reading strategies to trial. It is interesting to note that in both semesters, students indicated a clear preference for using graphical information as a way of increasing their understanding of content.

Student comments regarding additional reading strategies they use from the Fall 2019 semester:

- Try setting goals
- Listen to music and relate parts of reading to parts of text
- Find quizzes online relating to the specific exam covered in the course
- If I don't understand something, I use YouTube to find a "tutorial" that explains that topic
- I may like to try using typographical aids
- I see what I need to complete in the written lab, and paraphrase those things into a rough outline to follow
- I take notes and summarize
- Go from general skimming to specific intense dissections of sections I identify as important



(a) Use of graphical content

(b) Initially skim text noting general characteristics

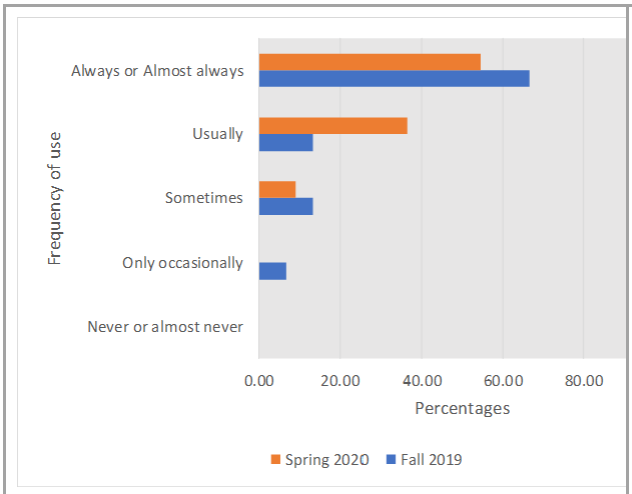
(c) Read with purpose

(d) Use context clues

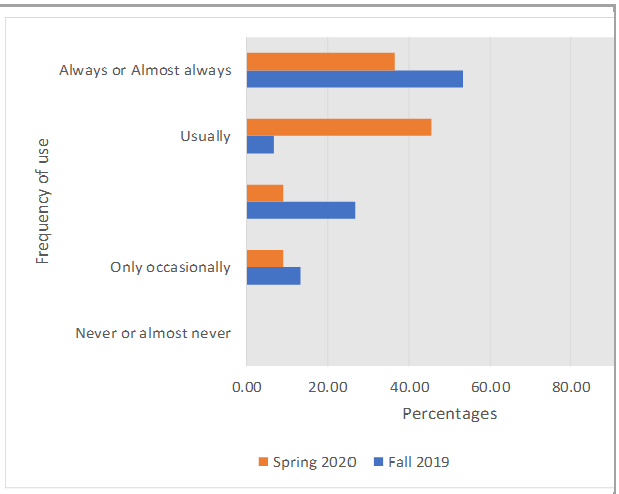
Figure 4. Global or generalized reading strategies most preferred in Network Switches & Routers in 2019-20

In the Spring 2020 semester students noted that they use these additional reading strategies:

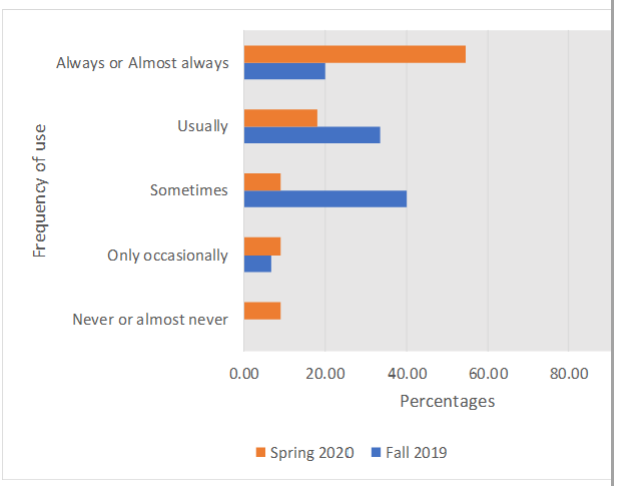
- I do further research, like look up articles people have written about a certain concept
- I use mnemonic devices to help me remember content
- Online explanations and organize info by topics that relate to one another
- Look for different explanations of concepts from alternate sources
- Try to find a video of someone explaining a topic that I couldn't completely understand
- Watch YouTube videos or Google questions I have and read what the internet says



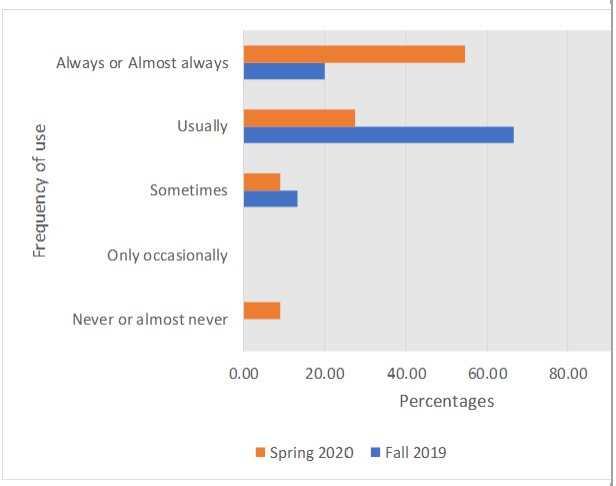
(a) Re-read difficult portions



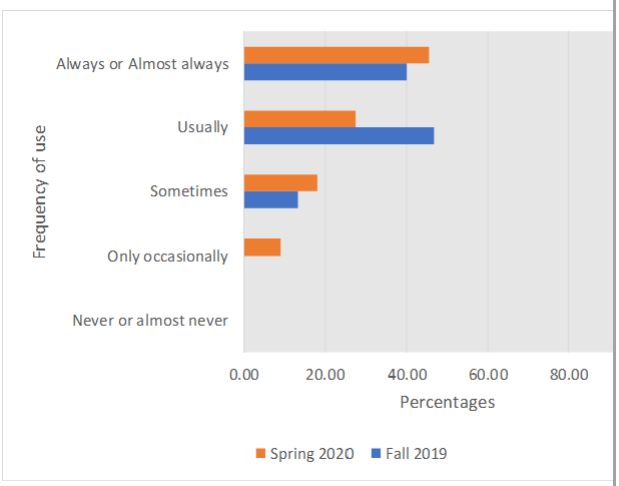
(b) Read slowly and carefully



(c) Adjust reading speed



(d) Get back on track after losing concentration

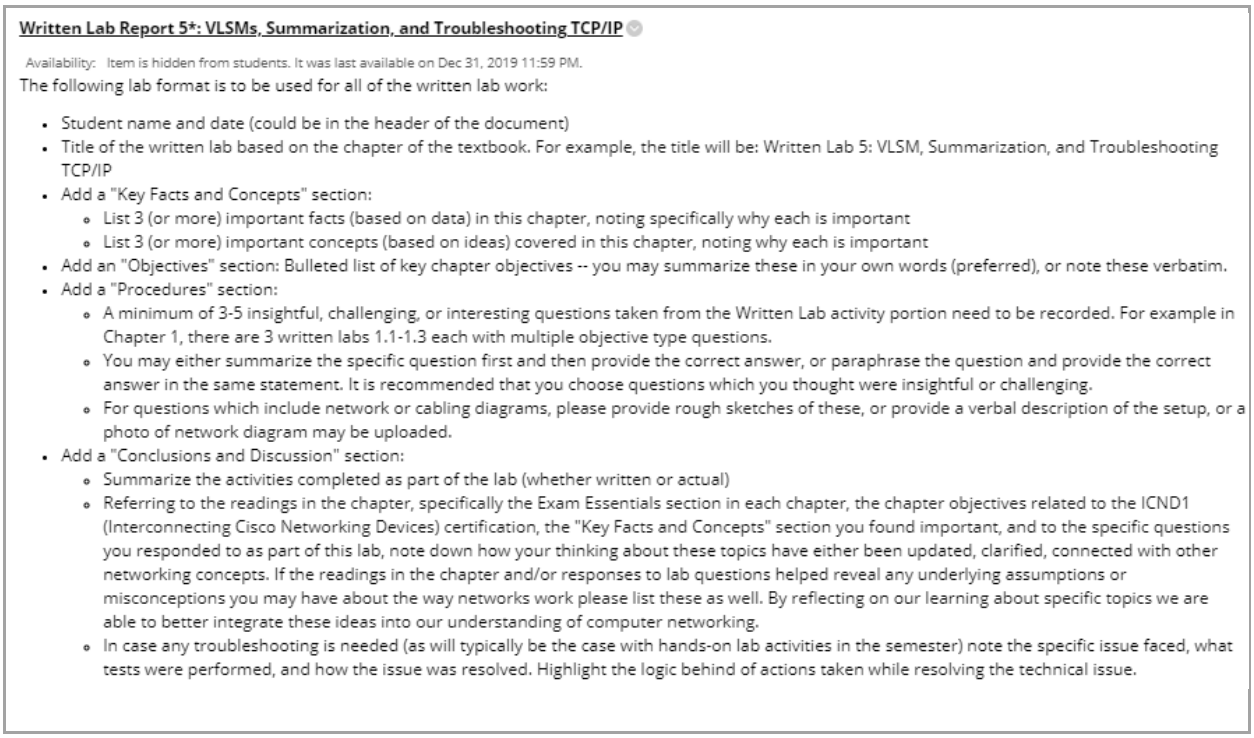


(e) Visualize information to help remember

Figure 5. Problem-solving reading strategies most preferred in Network Switches & Routers in 2019-20

Structured Reading Activities

A closer reading of the text is encouraged by requiring students to identify Key Facts and Concepts, conveniently labeled as KFCs for the chapter. Later in the semester, we expand the "s" in KFCs to stand in for "sequences" or "step-by-step" procedures needed while performing a series of tasks associated with laboratory activities. Figure 6 shows a sample of a written laboratory activity, from a chapter on Variable Length Subnet Masking (VLSM), a technique used to divide up networks into suitably sized sub-networks.



Written Lab Report 5*: VLSMs, Summarization, and Troubleshooting TCP/IP

Availability: Item is hidden from students. It was last available on Dec 31, 2019 11:59 PM.

The following lab format is to be used for all of the written lab work:

- Student name and date (could be in the header of the document)
- Title of the written lab based on the chapter of the textbook. For example, the title will be: Written Lab 5: VLSM, Summarization, and Troubleshooting TCP/IP
- Add a "Key Facts and Concepts" section:
  - List 3 (or more) important facts (based on data) in this chapter, noting specifically why each is important
  - List 3 (or more) important concepts (based on ideas) covered in this chapter, noting why each is important
- Add an "Objectives" section: Bulleted list of key chapter objectives -- you may summarize these in your own words (preferred), or note these verbatim.
- Add a "Procedures" section:
  - A minimum of 3-5 insightful, challenging, or interesting questions taken from the Written Lab activity portion need to be recorded. For example in Chapter 1, there are 3 written labs 1.1-1.3 each with multiple objective type questions.
  - You may either summarize the specific question first and then provide the correct answer, or paraphrase the question and provide the correct answer in the same statement. It is recommended that you choose questions which you thought were insightful or challenging.
  - For questions which include network or cabling diagrams, please provide rough sketches of these, or provide a verbal description of the setup, or a photo of network diagram may be uploaded.
- Add a "Conclusions and Discussion" section:
  - Summarize the activities completed as part of the lab (whether written or actual)
  - Referring to the readings in the chapter, specifically the Exam Essentials section in each chapter, the chapter objectives related to the ICND1 (Interconnecting Cisco Networking Devices) certification, the "Key Facts and Concepts" section you found important, and to the specific questions you responded to as part of this lab, note down how your thinking about these topics have either been updated, clarified, connected with other networking concepts. If the readings in the chapter and/or responses to lab questions helped reveal any underlying assumptions or misconceptions you may have about the way networks work please list these as well. By reflecting on our learning about specific topics we are able to better integrate these ideas into our understanding of computer networking.
  - In case any troubleshooting is needed (as will typically be the case with hands-on lab activities in the semester) note the specific issue faced, what tests were performed, and how the issue was resolved. Highlight the logic behind of actions taken while resolving the technical issue.

Figure 6. Sample prompts for written laboratory activities targeting reading skills

Responses to the laboratory activities specifically require students to indicate how their prior thinking about the topic has been challenged or extended, and any assumptions they were making clarified. This type of closer reading of the text, as suggested in [9], asks students to engage metacognitive processes, actively reflecting on their learning. Students read with purpose as they identify key facts and concepts in a chapter. They identify end-of-chapter laboratory or review questions they find interesting or challenging. They connect the reading with chapter objectives and are made aware of the importance of reading skills. Since the responses to lab and review questions are available, the activity is genuinely about self-assessment. In [12], the authors note the importance of desirable difficulties, such as testing for building resilient learning skills. In the context of responding to the end-of-chapter questions, students can identify which ones of these they require re-reading, perhaps adjusting the pace of their reading so that they can understand the concepts better and anchor their learning around crucial facts and ideas.

Additionally, as part of the written laboratory activities, students need to paraphrase essential facts and concepts covered in the chapter. Articulating what one thinks is important and why that is so is crucial in strengthening the understanding of complex topics. Additionally, students are encouraged to either freehand sketch network diagrams or provide verbal descriptions of the

system in enough detail. It improves observation skills, and in turn, allows students to detail out what they are observing. It improves their reading of visual content as well. This procedure can be readily adopted across other technology classes, as it combines low-stakes self-assessment, encourages the reading of the textbook, and a tell-back process. As a way to debrief following a reading of the assigned readings from the textbook, students can be encouraged to share out as part of class discussions their KFCs, and flexibly added to by the instructor, linking these ideas to previous or future topics in the course. This ideas of linkages between different topics, in fact across the curriculum, and beyond, into the workplace are crucial in building what I would term as Actionable Understanding (AU) for safely, effectively, and enjoyably, adapting theory to practice, especially under challenging scenarios.

One of the objectives of the course is to build competencies regarding reading technical content related to in-class discussions and activities. Technical resources abound on the Internet, and by extending the use of annotation from the textbook to any available website is a natural next step. We are currently exploring the webpage annotation tool Hypothes.is (https://web.hypothes.is/). It is being used mainly for generating personal annotations for technical content. It is quite an excellent resource to have open while browsing any website, technical or otherwise. Figure 7 shows a sample webpage annotation. Now the viewer can quickly leave notes, a trail of breadcrumbs, to explore at a later time.

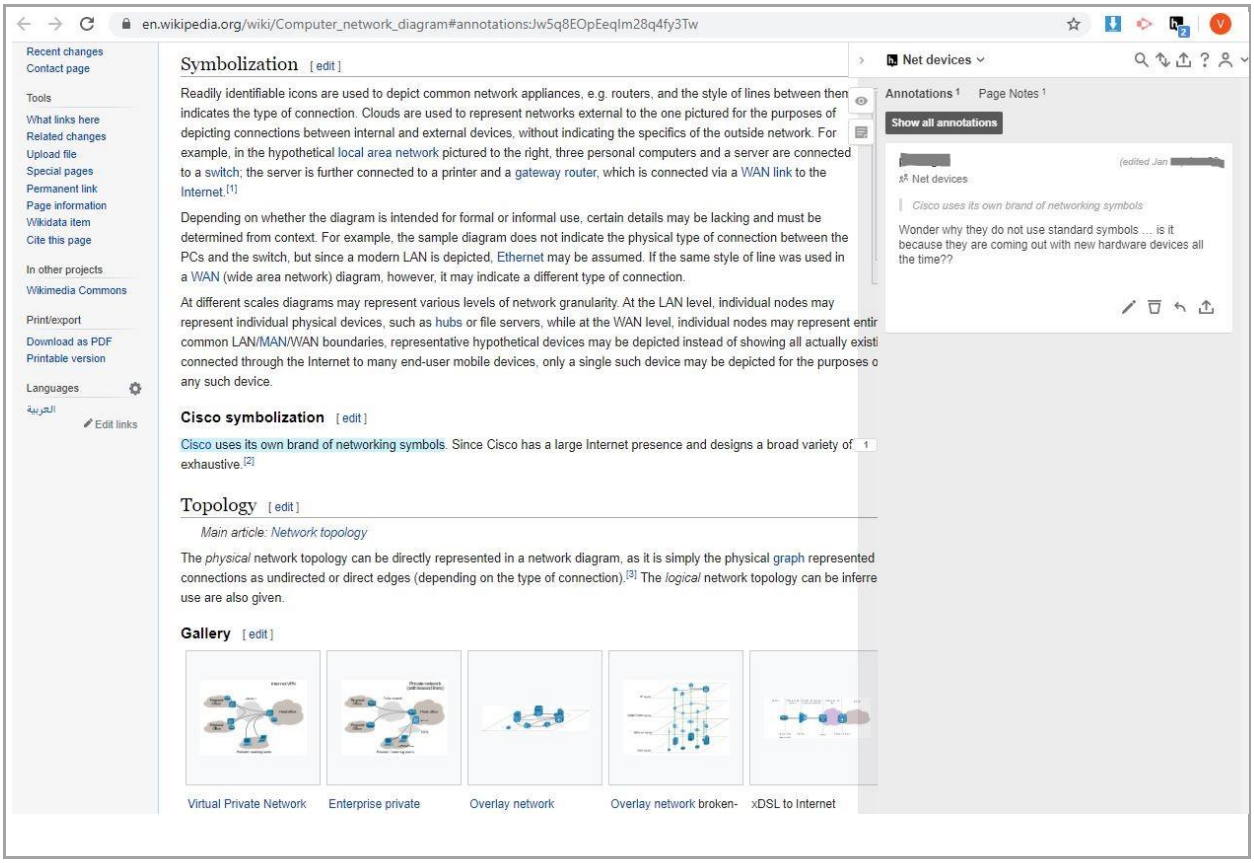


Figure 7. The Computer Network Diagrams Wikipedia web page shown here has been annotated using the open-source browser add-on Hypothes.is. We can annotate most Internet web pages using this free and easily accessible software.

Hypothes.is is available for login access through the https://web.hypothes.is/ webpage. This tool is also very easily added as a web browser extension, or as a Bookmarklet. The annotations or highlighting of web content do not need to be shared. Or they can be by students if they so choose. This year, students are being encouraged to include snippets of annotations in their learning portfolios. As the site allows adding annotations to any commercial copyright content, these images would be themselves subject to copyright, and thus care needs to be taken for honoring that.

Using Hypotheses.is and a screen clipping tool, students can save notes collected from different online sites to their online portfolios. They can also create different private (or public) groups if they wish to share the information with peers or colleagues at work. Its power is evident in Intranet pages, with questions sent to all group members inviting responses. It can encourage students to annotate as they read technical information online, saving their annotations for solving technical issues later or collaborating with peers. The power of the hypotheseis.is site is that it retains the annotations, allowing one to toggle between having it on and off during site access. It leaves clues about how many annotations are there as well, noting hot spots in the web document. In the future, the instructor plans to invite students are to submit at least five annotations from any computer networking technology websites, including sample screen clips of their annotations as part of their portfolios.

Learning both within the Network Switches & Routers classroom and beyond it can be strengthened tremendously by using specific reading strategies. It can be done by showing students how technology professionals in the area read and annotate technical texts and documents. Annotations help reveal one's thinking processes and feelings to oneself – which is quite incredible in and of itself – as some of these may is under layers of conditioning. Encouraging students to annotate textbooks, especially in the computer-oriented technology areas, which have specialized verbiage along with applied mathematics, can pose additional challenges: vocabulary and structure. When students annotate the textbooks as they read, they become active participants in the learning process, instead of passive recipients of the information provided by the author. Annotations can help us make sense of things, allow us to figure out patterns, and to connect the learning to one's individual experience. We strengthen the discipline-specific reading of technical content by offering opportunities for group-hands on laboratory activities, project-based learning experiences, and co-operative education with employers.

Assessment of Student Learning

Written-, simulation-, and hands-on laboratory activities, selected class worksheets including article/media reviews, portfolio review, a mid-term exam, and a final exam in the course determine student achievement of competencies. Comprehension of technical content scaffolded through structured activities such as the reading assignments, and notes which include visuals with verbal annotations (or the other way around). The final hands-on lab activity serves as the pinnacle configuration the students are trying to construct through the semester and serves to motivate their activities.

The mid-term and final assessments in the Network Switches & Routers class include a scenario-based section wherein a portfolio of notes and text resources is permitted. It encourages students

to organize their course portfolios ahead of time, including the feedback received from the instructor on in-class and written lab activities. As observed in [2], permitting students to use self-developed notes on quizzes motivates them to complete the readings.

By observing student work both in class and the laboratory, along with their written lab submissions, provide clear indications about the self-efficacy of students in the computer network area. Students are developing annotated network diagrams in response to specific scenarios, implementing their designs on the physical devices, and verifying that the overall network system works as intended. Included below is a self-reflection statement shared by a student regarding improvement in reading skills.

- *I have found myself to be a better reader because of the written labs. I am constantly annotating.*
- *Creating the portfolio has helped me be better at organization.*
- *Studying for test has also increased because I have better not taking in class.*
- *My time management is better because I look at what is most important and do that first.*

Comments regarding specific reading strategies are mentioned by students while completing the written labs. Here are some samples of student comments:

> *"I re-read the chapter one more time after finishing and it helps to go back and work problems more than once even when you know the answer. …I will better my skills in a way with loads of practice problems together. As stated above it is essential."*

> *"This chapter introduced us to the concept of subnetting, and by the end of the chapter effectively demonstrated how to subnet simple class A, B, and C networks. It gave formulas for solving questions without table banks and showed how to make said tables. This was the chapter I was most worried about coming into this class and having read and used it I feel much better."*

Summary student comments regarding reading comprehension and note taking in the Network Switches & Routers class are included below:

> *"Thorough book usage – It isn't often that I purchase books for my classes as usually they are not required, but I have found from this class that the Written Labs involving the objectives, procedures, and summaries of the chapter we've done are indeed helpful in retaining what we learn in class. Learning is repetition, and the best repetition includes another angle or perspective on the same information which helps one connect more ideas to it and keeps it rooted in mid for longer."*

> *"My work habits include taking clear and detailed notes from class, solving practice problems, and working proficiently in in-class exercises and lab activities."*

> *"I drew so many diagrams during this semester, but it turned out to be a good thing, because I can actually draw them from memory now without any problems."*

> *"My knowledge of networking and configuring network devices has increased significantly because of NET 343. This is due to learning about many different networking concepts in the textbook, seeing examples of how to configure different network devices in lecture, completing the worksheets that required me to use my knowledge of networking that I*

learned in class to solve and answer various types of questions that were related to networking, and the hands-on labs and simulation labs that required me to apply the knowledge."

"Being able to put the new information into practice and being able to run into stumbling blocks greatly solidified what I was able to take away from the lectures."

"My reading comprehension skills have been tested and exercised. The information I'm getting is less fragmented and I'm able to make connections between the raw material and tits practical applications. I've certainly have a learning curve, but I'm getting better.

"Using reference materials to solve problems or figure out processes is the skills I have improved the most upon in the second half, along with further reading comprehension improvement."

"In addition to the technical knowledge gained, I have developed practical habits for learning a new topic. Keeping well organized notes on the topic then applying what I've learned in some form of practice exercise helps solidify it in my brain. Keeping this portfolio and reviewing it has also been a bit help. I can see this being useful even after this class is over!"

Conclusions and Future Work

Purposeful reading of technical resources using self-developed textual and graphical annotations can improve understanding and application of the topic, a students' sense of control over their learning, linkages with others around the subject, and proficiency in the discipline. It, in turn, can help with the retention of students in the program.

The importance of critical reading skills cannot be overstated. Early and repeated opportunities for engaging with the reading of technical content is likely to result in the improvement of reading skills. Additionally, by familiarizing students with various reading strategies at the start of the semester, students may have more time to experiment with various reading strategies, as the content becomes progressively more challenging.

Having multiple reading strategies in their toolkit should allow them to flexibly adapt to the kind of reading for the task at hand. We regard this as part of an overarching goal for developing critical and creative thinkers who communicate effectively. An update to the student portfolios includes a "Key Facts and Concepts Glossary," possibly with an Index, which would make it similar to the one in their textbook. Doing so should allow students to create, as part of their course portfolio, a comprehensive reference of their learning through the semester.

Institutional level support of reading and metacognitive skills is vital for graduates entering the 21st-century workforce. Student tutoring and learning centers that offer training sessions on improving study skills could include workshops for strengthening reading strategies. It would be especially useful for supporting science and engineering programs that require students to effectively navigate enormous amounts of technical and increasingly media-rich content that includes interactive graphics and simulations. While recitations and laboratory sessions that typically accompany lectures in these classes can provide students with practical applications of theory, to develop better technical reading skills, additional instruction is likely to be helpful. By

building awareness of metacognition and reading strategies, students can build their repertoire of personalized tools, such as the use of self-developed verbal and visual annotations in their texts and notes.

Strategies for reading and annotation technical textbooks, along with other personalized ways of purposeful reading, have been explored in this paper. Recommended strategies before, during, and after reading technical documents can significantly improve comprehension, analysis, and appreciation of the subject. It can help reveal the underlying beauty of the concepts and motivate the student to stay immersed in the content.

Strategies for reading and annotation technical textbooks, along with other personalized ways of purposeful reading, have been explored in this paper. Recommended strategies before, during, and after reading technical documents can significantly improve comprehension, analysis, and appreciation of the subject. It can help reveal the underlying beauty of the concepts and motivate the student to stay immersed in the content.

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