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Qualitative Research

Effectiveness and Utility of Flowcharts on Learning in a Classroom Setting: A Mixed-Methods Study

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ABSTRACT

Objective: Graphical representation of information organizes and promotes meaningful learning. As an example of graphical organizers, flowcharts can simplify and summarize complex information. The evidence of classroom use of flowcharts as an instructional tool is unclear. We investigated the effectiveness of flowcharts on student learning as an in-class instructional tool in a cardiovascular therapeutic course. Student experiences with the use and application of flowcharts were explored.

Methods: An explanatory sequential mixed-methods study was conducted with pharmacy students enrolled in an acute-care cardiovascular course from 2019–2021. The quantitative phase comprised a survey to determine flowchart effectiveness and a comparison of student performance in three content areas. The qualitative phase of the study used focused group interviews to understand student perceptions of flowchart use.

Results: Survey results indicated that using flowcharts improved understanding (110/128, 86%), integration of material (114/128, 89%), and overall knowledge (111/128, 87%). Student performance in the 3 content areas, shock, arrhythmia, and acute coronary syndrome were statistically significant with flowcharts implementation. Emerging themes from student interviews were (1) used as a medium for retention and recall, (2) used as a study tool, and (3) used as a decision-making framework.

Conclusion: Flowcharts provide an alternative approach to teaching complex content, which allows students to organize and summarize information that promotes meaningful learning. The ease of implementation combined with the generalized nature of flowcharts makes it an effective graphical organizer that can be used across various disciplines

1. Significance Statement

The use of visual representation of knowledge using flowcharts as a post-instructional or formative assessment tool has been demonstrated, but evidence of its use as an active learning instructional medium in a classroom setting is lacking. Our study filled this gap by demonstrating that the active construction of flowcharts simultaneously with classroom instruction positively impacts student performance and facilitates learning. Flowcharts' simplistic diagrammatic framework offers an effective learning strategy for pharmacy students that aids in integrating, retaining, and recalling knowledge that can be utilized both in and outside the classroom.

2. Introduction

Students employ a wide range of visual representations, including concept maps, flowcharts, and notetaking, to enhance their thinking, reasoning, and problem-solving abilities.[1–4] These graphic organizers play an important role in facilitating the retrieval of information, recall, preparing for assessments, and promoting learning outside of the traditional classroom setting.[1,5–7] Numerous studies on metacognition have supported the effective use of graphic organizers in the learning process.[8,9] Flowcharts are examples of visual representations that effectively present, graphically organize, and display ways to solve problems by offering a visual understanding of complex information.[10,11]

Flowcharts can effectively enhance nuanced understanding, retention, recall, and the ability to establish meaningful connections with the material. Flowcharts' visual and diagrammatic nature simplifies

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complex information, aiding in decision-making processes. For example, a study conducted by Conway and colleagues[12] demonstrated that using flowcharts significantly improved the selection of ointment bases in a pharmaceutics laboratory course. Another study by Wilson and colleagues[9] revealed that student-drawn flowcharts fostered a deeper understanding of scientific processes and facilitated the integration of concepts. The integration of concepts is particularly enhanced due to the visual cues provided by graphic organizers like flowcharts, allowing for the illustration of relationships and the connection of various ideas.[2,4] Like concept maps and other graphical representations, flowcharts effectively connect new information to existing knowledge.[1,5] This interconnected approach to learning creates a contextual and meaningful learning experience, aligning with the principles of cognitive constructivism, as reported in the literature.[13] In contrast to concept maps, flowcharts offer a versatile framework that accommodates the integration of diverse subject areas, making them a valuable resource for classroom notetaking.[9] As a result, flowcharts serve as an excellent platform for teaching pharmacotherapeutics-related courses, as they can facilitate the integration of foundational and clinical sciences within a simplified framework, leading to improved understanding and learning.

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Previous studies reported using flowcharts as a post-instructional or formative assessment tool. However, evidence examining flowcharts used as an active learning instructional medium in a classroom setting is lacking. In addition, the various ways students used flowcharts for their learning have not been reported. The purpose of this mixed-methods study was to address this gap by employing quantitative data analysis to investigate the impact of flowcharts as an active in-class instructional tool on student learning and performance in an integrated cardiovascular pharmacotherapeutics course for pharmacy students. Furthermore, we used qualitative data to describe how flowcharts can influence student performance, including their utility in integration, recall, and understanding, thereby facilitating the learning process. This study employed flowcharts as classroom notes. In contrast to traditional guided note-taking, which follows a linear process, we explored the utility of notes in the form of a flowchart. The results of this study will provide evidence that graphic organizers such as flowcharts offer an effective learning strategy for pharmacy students both in and outside the classroom.

3. Methods

We employed an explanatory sequential mixed-method design (QUANT→qual) for this study because this design facilitated a comprehensive analysis of the results and allowed for generalizable meta-inferences.[14] In the quantitative phase (QUANT), we administered a survey to collect ratings regarding the necessity and effectiveness of flowcharts, in addition to analyzing student performance data. However, relying solely on quantitative data may not reveal how students utilized flowcharts and their impact on learning. To address this potential gap, we conducted semistructured interviews with students to gain a deeper understanding of their experiences with flowchart utilization. By exploring qualitative (qual) themes, we aimed to elucidate the diverse ways in which students incorporate flowcharts into their learning and assessments. While the quantitative data provided the numbers, the qual narrative provided insight that added depth to enrich the results. Thus, integrating the results from both phases allowed us to contextualize the quantitative constructs and obtain additional information regarding the utility and effectiveness of flowcharts to facilitate learning.

The study was conducted at Western New England University, College of Pharmacy and Health Sciences. The second-year Doctor of Pharmacy students enrolled in the Integrated Pharmacy Care & Patient Management Cardiovascular II (IPC-CVS-II) module were invited to participate in the study. The study was conducted from 2019 to 2021, and the authors (A.Z and D.B) have coordinated the course since 2017. The Western New England Institutional Review Board approved the research study. The course integrated pathophysiology, pharmacology, and pharmacotherapeutics of 3 complex acute-care cardiovascular disease states (described as content areas in the manuscript); shock, antiarrhythmic, and acute coronary syndrome.

Flowcharts are designed using symbols, standardized basic text, and/or graphic elements that are connected with arrows representing the direction of information and process. The flowcharts (input boxes, arms, decision diamonds) were designed based on the American National Standards Institute guidelines.[10] We used an implementation flowchart type because it provided an outline connecting prior knowledge to new knowledge and displaying decision-making steps. In previous reports, flowcharts were used as post-instructional formative assessments, thus, they reflected pre-existing knowledge. In our case, the flowcharts were built around a framework that connected students' existing knowledge with new knowledge. Furthermore, our distinctive instructional approach involved collaborative completion of the flowcharts during class, incorporating active student participation in the construction of these graphic organizers. Before each class, the flowcharts' outline (incomplete boxes and arms), cocreated by the pharmaceutical sciences and the clinical faculty, was uploaded to the University's Learning Management System (LMS). Pre-reading was suggested before class but was not required. The flowchart topics were cotaught by the pharmaceutical sciences and clinical faculty. Each flowchart step was completed by handwriting the information using a smartboard with a stylus. The input or decision boxes could include details on the pharmacology of medications, signs/symptoms, pertinent labs, and therapeutic decision-making for a disease state. The handwritten flowcharts complemented the lecture notes from the didactic portion of the class and were posted on the LMS at the end of each class period (Appendix 1.1).

Traditional guided notetaking is a linear process, whereas in our case, the notes were presented to the students in the form of a graphic organizer (ie, flowcharts). Previous literature has highlighted handwritten notes' effectiveness combined with in-class participation.[15] The previous study primarily featured diagrammatic illustrations as notes, often centered on pharmacology, in our study, flowcharts integrated diverse content areas such as physiology, pharmacology, and pharmacotherapeutics. While earlier usage of flowcharts primarily entailed post-instructional assessments, our design involved constructing the flowcharts during class sessions. This dynamic approach allowed us to actively connect new knowledge with pre-existing information. Another feature of our instructional design was that at each step in actively completing the flowchart, the instructors solicited student responses, prompted questions, encouraged discussion, and requested a rationale for each response. This scaffolded instructional strategy incorporated student input, which helped them build relationships between concepts. This collaborative approach actively engaged the students and facilitated learning. In addition, it also allowed the students to transcribe their understanding of the content during class and write down any additional information not handwritten in the instructor's flowcharts.[15]

A diagram illustrating the mixed-methods design is shown in Fig. 1. In the QUANT phase, students enrolled in the IPC CVS-II course were invited to participate in a voluntary (with no compensation) pre- and post-survey on the effectiveness of flowcharts using a 5-point Likert-like rating scale (Strongly agree to Strongly disagree). Three students from the 2019 class and 2 faculty members were asked to review the initial survey and provide feedback. Students' performance was measured as scores in the 3 content areas (shock, antiarrhythmic, and acute coronary syndrome) on the summative examinations with (2019–2021) or without flowcharts (2017–2018). The data were analyzed using SPSS (version 28.0.0.0, Chicago, IL). Once the assumptions of normality and

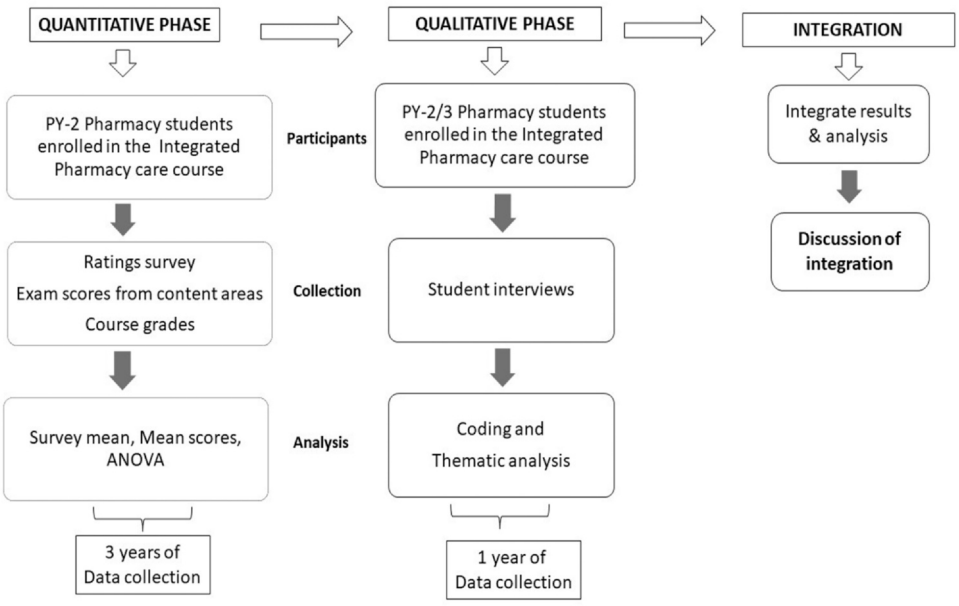

Fig. 1. Schematic of the explanatory sequential mixed-methods study design.

homogeneity were met, a one-way analysis of variance was used to determine the effectiveness of student performance, and the descriptive statistics for each cohort were recorded.

The analysis from the QUANT phase informed the development of 5 interview questions for the qual phase (Appendix 1.2). Students from 2019, 2020, and 2021 classes were invited (by email) to participate voluntarily in the focus group interview sessions. The interviews took place between April and May 2021. These questions were sent out to 3 pharmacy students (2021 class) for feedback, and changes were made accordingly. Semi-structured interviews were conducted with 5 participants per group; the average interview time was 40 min. General follow-up questions to clarify and invitations to elaborate were used. Interviews were recorded, transcribed verbatim, and deidentified and analyzed by inductive coding using the NVivo-12 software. The researchers met in 2 separate meetings to finalize the focus group interviews' codes, categories, and emerging themes. A narrative approach was used to integrate the findings from the QUANT and qual phases of the mixed-methods study.

4. Results

All students enrolled in the IPC-CVS-II course for Spring 2019, 2020, and 2021 were invited to participate in a pre- and post-flowchart questionnaire ($n = 128$). Females accounted for the majority of each cohort: 2019 ($n = 46$, 74.1%), 2020 ($n = 40$, 66.7%), and 2021 ($n = 29$, 55.8%). Results from the pre-flowchart survey reported that the majority of students (74%) agreed that flowchart use would help improve understanding and help integrate pharmacology and pharmacotherapeutics content areas (75%) (Table 1). The post-intervention survey indicated that the students found the use of flowcharts beneficial for learning. The students thought that flowchart implementation improved overall knowledge (87%). The results indicated that the use of flowcharts improved their understanding of pharmacology (80%), and pharmacotherapeutics (86%), and the integration of content areas also improved (89%). Overall, the students positively responded to the use of flowcharts and thought it helped integrate pharmacology and pharmacotherapeutics and aided their learning and understanding.

Student's performance in the summative examinations in the 3 content areas (shock, antiarrhythmic, and acute coronary syndrome) with (2019–2021) or without flowcharts, 2017 ($n = 66$, female = 56%) and 2018 ($n = 68$, female = 38%), was collected. All scores were gathered for 2019 ($n = 62$, female = 77%), 2020 ($n = 60$, female = 66%), and 2021 ($n = 53$, female = 60%) cohorts after the final semester grades were submitted. The independent variable was the use of flowcharts as the intervention, and student performance recorded for the shock, antiarrhythmics, and acute coronary syndrome exams was the dependent variable. There were statistically significant differences between the groups in achievement score, $F(1307) = 5.40$, $P < .05$, $\eta 2p = 0.017$, indicating that the use of flowcharts explains approximately 2% of the variance (or variability) for the shock scores (Table 2). Thus, flowcharts are associated with improved student performance for the shock examinations in the IPC-CVS-II course. There were statistically significant differences between the groups in achievement score, $F(1307) = 4.27$, $P < .05$, $\eta 2p = 0.014$, indicating that the use of flowcharts explains approximately 1% of the variance (or variability) on antiarrhythmic scores (Table 2). Similarly, there were statistically significant differences between the groups in achievement score, $F(1307) = 5.42$, $P < .05$, $\eta 2p = 0.017$, indicating that the use of flowcharts explains approximately 2% of the variance (or variability) on acute coronary syndrome scores (Table 2).

A comparison of course grades between 2017–2018 and 2019–2021, revealed a decline in the number of students failing the course following the use of flowcharts (13.5% in 2017–2018 vs 9.5% in 2019–2021). We also observed a notable increase in the number of students receiving a grade of B (33.5% in 2017–2018 vs 43.5 in 2019–2021) and a declining number of students receiving a grade of C (42.1% in 2017–2018 vs 36.5 in 2019–2021) (Fig. 1). The percentage of students receiving a grade of A in the course remained the same (10.7% in 2017–2018 vs 10.4% in 2019–2021). Overall, the QUANT results indicated that the students positively viewed flowchart implementation, and it significantly improved student performance.

For the qual phase, interviews were completed by 12 students, with students from all classes, 2019–2021 (10 from 2021, 2 from 2020, and 1 from the 2019 class). As shown in Fig. 2, the coding analysis yielded 21 codes placed into 4 categories. Three major themes emerged from the qual analysis, namely “used as a medium for retention and recall,” “used as a study tool,” and “used as a decision-making framework.” Themes and quotes from student interviews regarding their views on flowchart utility and purpose are listed in Table 3.

Our coding analysis on flowcharts use indicated that it helped break down the information and provided an organized framework that facilitated student understanding of the content. For instance, one student

Table 1
Responses to Survey Using a 5-Point-Likert Scale Administered to Pharmacy Students Enrolled in an Acute-Care Cardiovascular Course.

Item	Preflowchart (*n* = 128)			Postflowchart (*n* = 128)		
	Strongly agree/ Agree, %	Neutral, %	Strongly disagree/ disagree, %	Strongly agree/ Agree, %	Neutral, %	Strongly disagree/ disagree, %
Posted lecture materials were reviewed before class	20	28	52	73	15	12
Flowcharts integrating pharmacology and therapeutics content helped with my understanding of pharmacology of drugs	70	11	19	80	12	8
Flowcharts integrating pharmacology and therapeutics content helped with my understanding of therapeutics	74	6	20	86	8	6
Flowcharts integrating pharmacology and therapeutics content helped my understanding of the role of drugs in disease states	75	15	10	89	8	3
Flowcharts integrating pharmacology and therapeutics content helped me get more interested in the course material	65	15	20	74	14	12
Flowcharts improve my overall understanding and knowledge	74	9	17	87	8	5

n for Agree/Strongly agree and n for Disagree/Strongly disagree are combined.

noted, "basically makes it easier to understand and break down into simple sections." Students described that using flowcharts provided a context to learning pharmacology and thus helped to integrate pharmacology with the pharmacotherapeutic content. Flowcharts provided a visual display that assisted students in recalling and retaining information, particularly during the assessments. One student noted, "because I'm a very visual person, and I can kind of visualize things in my head, so I saw the kind of steps in my head, as I was taking the exam so something that was as visual as the flowcharts was beneficial for 3 CVS exams for me." The flowcharts that were drawn and posted by the instructors on the course LMS were not allowed during assessments. However, students recreated their own flowcharts during assessments from memory (Fig. 3).

Our results found that flowcharts could be used as a 'quick study guide' and 'study tool.' Students agreed that the simple outlines of information on the flowchart made them a quick reference and "really helped me put everything together in my brain." The flowcharts provided a means for the students to connect information and thus aided understanding, "I think that was because I went through the flowcharts so much, and I really understood what I was learning."

The students described that integrating pharmacology and pharmacotherapeutics within the flowcharts was beneficial in understanding the decision-making process used in pharmacotherapy, and this combined approach was helpful in studying for assessments. Students also said that learning the pharmacological rationale for drug use and place in therapy of a drug was easy with flowcharts. Several students discussed that the use of flowcharts created efficient use of study time. While describing perceived utility in other pharmacotherapeutic courses, one student noted, "what I would also do is I would try to do like a simplified version like on the exam when we had that piece of paper I would kind of jot down the flowchart in very simple terms." Almost all of the students perceived that using this framework contributed to better academic outcomes in this class.

The emerging codes from the thematic analysis (qual) supported the QUANT results. Codes such as "Recall," "Retain information," "Visual imagery," and "Quick reference" supported the improved results on student performance and overall course grades. The codes such as "Simplifying topics," "Organize content," and "Integration of content areas" further explained and supported the survey results.

5. Discussion

Didactic lectures present a wide range of information in a short amount of time. However, this type of instruction does not help the student organize and access knowledge easily. Graphical representation of information using flowcharts provides a knowledge structure that promotes meaningful learning. Our results indicated that flowcharts used in a cardiovascular therapeutics course designed for pharmacy students presented an effective learning strategy for pharmacy students that aid in integrating, retaining, and recalling knowledge. The connection between subject areas was markedly enhanced with flowchart use, facilitating the integration of course content. The implementation of flowcharts significantly improved student performance, thus demonstrating its impact on improved learning.

Unlike knowledge maps or concept maps, flowcharts do not require hierarchical organization or linkages between nodes. The instructions for flowchart completion were indicated by the prompt and the direction of the arrow; thus, students can construct them easily. However, it has been shown that students with prior experience may be better at drawing flowcharts.[9] In addition to pharmacy,[12] the ease of construction allows for transferability to other professions such as engineering,[16] medicine,[5] and law.[7] Students easily visualize complex information packaged as a mental image and tend to remember information that is verbally relayed during class.[17,18] Converting verbal information into a visuospatial graphic such as a flowchart provides a tool for students to store and retrieve information from long-term

Table 2
ANOVA Results and Descriptive Statistics for Student Performance in the 3 content areas (shock, antiarrhythmics, and Acute Coronary Syndrome) With or Without the Use of Flowcharts.

A. Student performance

	Shock M (SD)	F	Antiarrhythmics M (SD)	F	ACS M (SD)	F
Without Flowchart (n = 134)	75.72 (13.11)	5.40[a]	71.71 (13.88)	4.27[a]	73.98 (10.87)	5.42[a]
With Flowchart (n = 175)	78.81 (10.27)		74.61 (10.79)		76.98 (11.44)	

Abbreviations: ACS, acute coronary syndrome; ANOVA, analysis of variance; F, XXX; M, mean.
[a] $P < .05$.

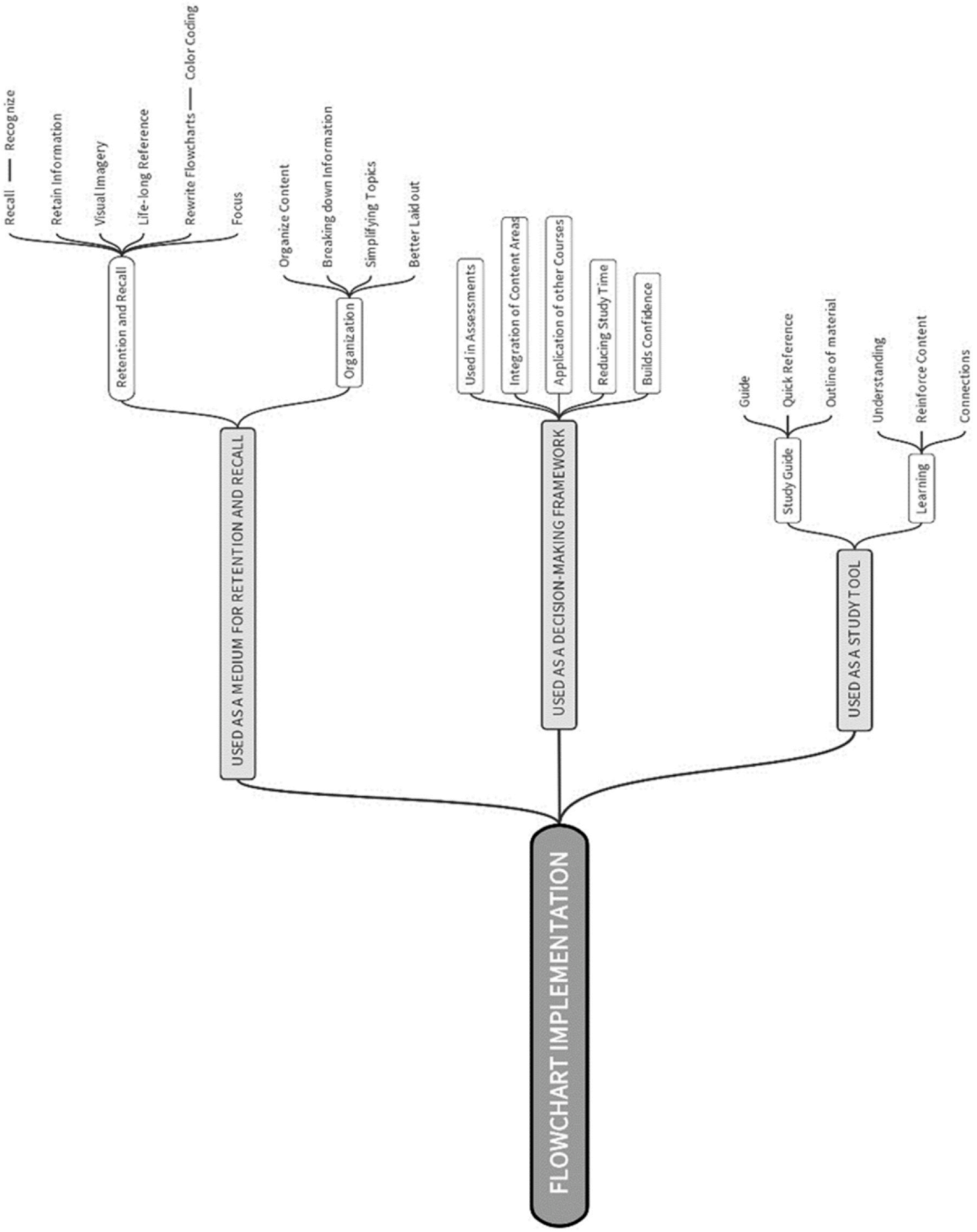

Fig. 2. Final coding scheme for flowchart use and implementation among pharmacy students enrolled in an acute-care cardiovascular course.

Table 3
Themes and Quotes From Student Interviews Regarding Their Views on Flowchart Utility and Purpose.

Themes	Category	Student quotes
Used as a medium of retention and recall	Organization	Definitely needed to know for the exam like consolidated into like one sheet, which was really helpful because, for me it could get really overwhelming, so to have like on one piece of paper that had everything that you absolutely needed to know like bass line information that you need to know all in one place was really helpful for me.
		I would say, because you understood you knew where everything was supposed to connect. It was your turn it was like your time to figure out, how and why it connected.
		like antiarrhythmic I used drugs that target rate, and then I would write like how so type of thing. And then I have rhythm in a separate area, and even if it repeats I just highlight the mechanism of what works for each one, so and it really helps kind of understand why we're treating the disease state.
	Retention and Recall	Because I will like I've said it helps me remember what I put where because I can visually see it, but then it helps me to like recall.
		I think what the flowcharts do for me is they kind of take the stress out of memorizing like everything on the slides, so it just gives you like a linear way to focus.
		I recognize what it (flowchart) was based off of like the symptoms are like their vitals or something, then I would find myself like drawing at the flowchart and making sure I didn't miss any steps when it came to like retaining the information.
		I do is that I just write the whole flowchart in color because, if I write it in black ink. then it just reminds me the slides and it gets very over overwhelming.
Used as a study tool	Study guide	Prepare for an exam because right out of the gate I had this whole layout in front of me that I could refer to when I was studying and that's probably something that I would have done by myself if we hadn't done in class as well.
		That was really, really helpful and I think it probably shaved a lot of time off of what I had to do studying like on the back end.
	Learning	That was really, really helpful and I think it probably shaved a lot of time off of what I had to do studying like on the back end you can use that time for like better studying almost like more like actual studying of what you're supposed to know.
		It gives me like a sense to figure out what's going on with a patient like if they have this problem then here's like what you need to do, and here are the possible options of treatments so it's definitely helped me out a lot to just break everything up together and then just see that big picture as a whole.
Used as a decision-making framework		I want to find an example, I know, like for stable angina we went through the hallmarks and then the treatment and then at the bottom, we went through like the pharmacology kind of recap of MVO2 so and supply and demand, so that makes it like really easy to put those different concepts all into one for me definitely good.
		Not that I like did not know what a flowchart was, but I think after CVS to I really understood how valuable that could be and I wish that I had done that or had been exposed to it before.
		Okay, I know, like all these steps like I am good to go it was kind of less overwhelming than having to like shuffle through all of your notes and be like oh my God I am forgetting something, because it was like right there in front of you.

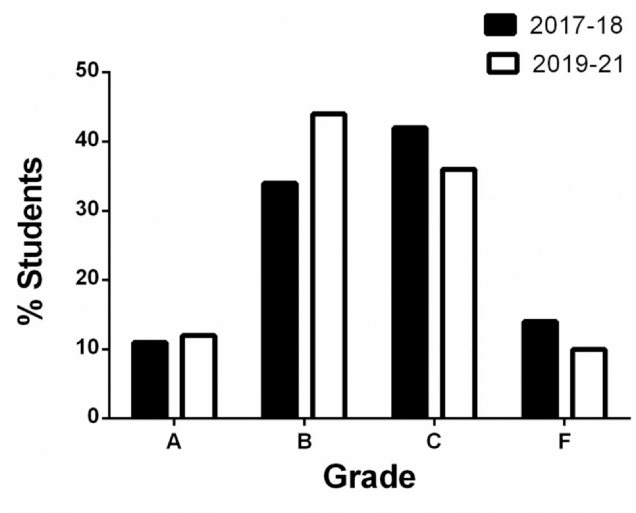

Fig. 3. Distribution of final course grades from 2017 to 2021 for students enrolled in an acute-care cardiovascular course.

memory,[4] and aids in quick and efficient learning.[19] In congruence with our results, using knowledge maps in a cardiovascular and gastrointestinal course in a pharmacy curriculum improved overall comprehension of the subject and examination scores.[20] In the current study, the instructors also encouraged student notetaking by completing the handwritten flowcharts during class. Notetaking reduces distraction, keeps students focused on learning, and positively correlates to student learning.[15,21] Additionally, writing notes synchronously during class increases the likelihood that students will document key ideas emphasized by the instructor during class.[21] The handwritten notes depicted as graphical or pictorial representations can also help students identify and retain relevant information.[3,15] The open-ended prompts during the flowchart session helped the students translate verbal information into the flowchart graphic, thus helping students connect and develop an understanding of key concepts in a systematic manner.[22] By providing a "big picture" view of the information, flowcharts can identify key information and demonstrate the interactions between concepts that help to understand the complex subject matter.[7] Moreover, the student's potential to apply this complex information and knowledge increases with flowcharts.[23,24] Thus, integrating new content with existing knowledge using flowcharts provides the scaffolding that promotes meaningful learning and retention.

This study does have several limitations. First, we did not assess the ability of the students to create their own flowcharts; however, some students stated that they redrew the charts or developed their own for other courses. Secondly, minor changes to the syllabus were made across the 5 years. For instance, since 2019, formative assessments were revised from 15% to 20% of the grade, and a summative exam was added. While the exam questions across the 5 years did not change substantially, the questions were revised or deleted based on item analysis. Although we would have liked to maintain consistent assessments, student learning was our priority. Third, it is possible that while every student in 2019–2021 was exposed to flowcharts, not every student could have used flowcharts during assessments. Fourth, there was no comparison of qualitative analysis between the nonflowchart and

flowchart cohorts.

Future studies are needed to determine the long-term impact of flowcharts. First, a follow-up study examining the ability to recall content-specific information using flowcharts at various time points during the students' academic years will help us determine the effectiveness of flowcharts on understanding and retention. Second, investigating how the students incorporate the flowchart during their clinical rotations or in practice will highlight the impact on recall and learning.

6. Conclusions

Overall, the impact of flowcharts in facilitating understanding and promoting meaningful learning was significant. The visual representation of information on the flowcharts provided students cues for recalling information, consequently improving student performance. As an instructional tool, it facilitated content integration and easily connected prior knowledge with new information. The generalized nature of the flowcharts, combined with the ease of implementation, makes them an effective learning strategy that can be used across various disciplines.

Author contributions

Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Supervision: **Anthony E. Zimmermann.** *Validation, Formal analysis, Investigation:* **Ethan King**. *Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Data curation, Formal analysis, Visualization, Supervision:* **Diptiman D. Bose**.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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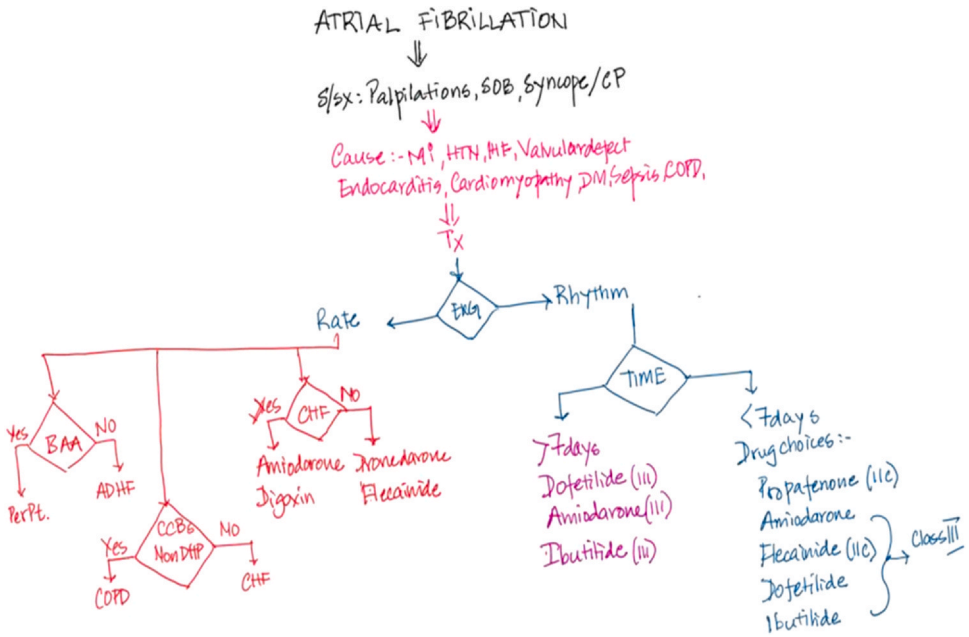
Appendix



Appendix 1.1. Example of a flowchart as completed by the instructors in class teaching the treatment of atrial fibrillation.

Appendix 1.2
Student group interview questions.

	Interview Questions
1.	Tell us in your own words how did you use the flowcharts for learning the material in the course? (Follow-up = In what way did you find it helpful for learning or not helpful?)
2.	Did the use of flowcharts help you understand the integration of content of pharmacology and therapeutics in the lectures and the module?
3.	Did you feel that using flowcharts would help you organize information for complex topics?
4.	Tell us in your own works if flowcharts helped you retain and recall information during exams? (In other words, was it helpful during an assessment or not?)
5.	Did you use the flowcharts to create your own notes or use it in other classes? Would you use flowcharts when you are studying in other classes?

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