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Mind mapping to enhance critical thinking skills in respiratory therapy education

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Abstract:

BACKGROUND: The objective of this study was to investigate the use of mind maps as an active teaching strategy to enhance critical thinking skills (CTSs) among respiratory therapy (RT) students in Saudi Arabia.

MATERIALS AND METHODS: A total of 86 participants from two RT programs in Saudi Arabian Universities, King Saud bin Abdulaziz University for Health Sciences and The Batterjie Medical College, were randomly assigned to either the mind map group (MMG) or the standard note-taking group (SNTG). With the quasi-experimental design and quantitative method, mean comparisons were made between the groups using an independent *t*-test.

RESULTS: There was no significant change between the pre-SNTG and post-SNTG as measured by the health sciences reasoning test (HSRT) after 15 weeks of standard note-taking (SNT). However, it showed the difference between the pre-MMG and post-MMG ($P = .02$) as measured by the HSRT after 15 weeks of intervention. There was also a significant change between the post-MMG and SNTG ($P = .04$) as measured by the HSRT, where the MMG had higher scores. However, the study had limitations, which conceded to the failure of participants in the test and the subjectivity of respondents where they were excluded from the study; also, for generalizability of the result, the study should have been taken beyond Riyadh and Jeddah.

CONCLUSION: Prior to this study, the effectiveness of mind mapping (MM) in the respiratory discipline has not yet been explored. It found that mind mapping was effective at improving CTS, while SNT was not, as measured by pre- and post-test HSRT scores. This was the first investigation into MM's impact on CTS within respiratory therapy education.

Keywords:

Active learning, learning strategy, mind mapping, respiratory care, respiratory therapy, standard note-taking

Introduction

Respiratory therapy (RT) is a rapidly emerging profession in allied healthcare, necessitating professionals to have critical thinking skills to treat life-threatening patients efficiently.[1] Educational programs must prepare RT students to cross the threshold of the workforce as competent entry-level practitioners, certifying they have the necessary critical thinking skills (CTSs) to infuse sound evidence-based practices and meet the needs of critically ill patients.[2] According to Lubken, T. A. (2021), respiratory care educators can promote CTSs in students through active engagement in the learning process using approaches such as peer teaching, peer evaluation, problem-based learning, evidence-based care guideline assessments, self-reflection,

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clinical simulation, case studies, and presentations.[3] Web-based curricula and technological advances also enhance critical thinking. Online learning surroundings and flipped classroom models have been used in RT programs to enable learning and transfer knowledge into clinical care plans.[4] Jaswal Behera[5] (2023) state that healthcare education programs must continually re-assess and plan learning environments that endorse reflection, knowledge building, problem solving, inquiry, and critical thinking to address trials in engaging the students.

Mind mapping (MM) was created on the constructivist learning theory, which advocates that learning is an active and constructive process where new information is associated with prior knowledge and past experiences.[6] This theory suggests that meaningful learning occurs when learners conform to new information within their pre-existing knowledge or framework. Constructivism theory suggests that understanding of a concept is constructed rather than acquired, with educational theorists like Dewey, Bruner, and Ausubel at variance that pre-existing knowledge and experiences impact learning.[7] Successful linking leads to abstract concepts in learners' minds, which organize their knowledge and help them understand new ideas.[8] Meaningful learning follows when new information is integrated into already existing knowledge, and mapping allows the presentation of new material to build on existing knowledge.[9,10]

Critical thinking is a domain-specific skill that necessitates knowledge and practice over time, prejudiced by individual cognitive development and stages of development.[11] It is essential for effective problem solving and requires early education and life experiences. MM promotes critical thinking by assimilating acquired information with pre-existing knowledge, aiding in retention and memory, and augmenting problem-solving skills.[12] As the workforce demands RTs, academic programs must encourage CTSs, but limited time imposes robust teaching and learning strategies.[13] MM has been efficacious in improving CTSs in health professional students, but its effectiveness in RT students remains unclear.[14]

Increasing demands for RTs in the workforce require academic programs to promote CTSs, but limited time requires robust teaching and learning strategies. For example, standard teaching methods like notes and outlines lack creativity and association, while MM facilitates information organization, enhancing knowledge acquisition and CTSs.[15-19]

As a teaching and learning methodology, MM has been a successful mode of improvement for CTSs in various health professional students; nevertheless, its use has not been searched explicitly in RT.[20] Therefore, it cannot be concluded that this strategy would be effective for RT students. Accordingly, this study explicitly investigated its application in this population.

Critical thinking in RT

Alhamad, B. R. (2016), mentioned a study by Mishoe (1995) identified seven CTSs for registered RTs: prioritizing, anticipating, troubleshooting, communicating, decision-making, negotiating, and reflecting.[21] Prioritizing is crucial for new patient admissions, while anticipating and troubleshooting are essential for patient care.[10,15-18] Effective communication and negotiation are crucial for decision-making. Reflecting helps improve critical thinking in critical situations.[22] RT faculty should employ effective teaching strategies to boost CTSs in respiratory education.[23]

MM as a learning strategy

Active learning in medical education promotes critical thinking from side to side through active learning strategies like MM. MM, a brain-based active learning strategy, accommodates students at the center of learning, enabling analysis, memorization, and understanding of concepts.[6] It enriches knowledge acquisition, retention, and critical thinking.[24] Further research is needed to search for its use in healthcare education and its welfare.

MM in nursing

Mueller *et al*.[25] (2002) found that using MM with nursing students in combination with care planning promotes critical thinking and holistic nursing care. Traditional columnar formats, such as linear ones, inhibit a holistic view of patients. MM helps students focus, organize thoughts, and make connections, promoting holistic thinking. Using colors and diagrams helps in knowledge recollection and creative integration.[26] It has been found that MM is effective in facilitating active learning among associate degree nursing students, stimulating radiant thinking and knowledge attainment.[27] These benefits are crucial in healthcare education to produce high-quality practitioners who can think critically, evaluate, and treat patients effectively.

MM in medicine

Medical students have displayed improved short-term and long-term memory recollection of genuine information using MM as a learning strategy.[27] However, studies propose that MM may not effectively stimulate short-term memory retention. Despite this, MM is effortlessly taught, is cost-effective, and can help establish information. It may also advance critical thinking in medical students. Medical education supports employing MM as a learning strategy as it

can help improve traits for critical thinking and patient care.[28] Studies on the connection between MM and critical thinking are essential.

MM in physical therapy

Research on the efficiency of mindfulness meditation (MM) in physical therapy is limited.[29] A study found that most students did not distinguish MM as helpful in organizing, prioritizing, or integrating information. However, some students were able to organize, prioritize, and integrate course material more effectively. Regardless of the negative results in this small pilot study, MM still assisted some students in organizing material (38%), prioritizing information (9.5%), and integrating course material (33.3%) more effectively.[23] Pollard's study found that MM did not proliferate communication skills or knowledge retention.[30] A subsequent study found a positive alteration in CTSs in physical therapy students after executing MM as a learning strategy.[31]

The present study aims to determine the CTS level of RT students using the health sciences reasoning test (HSRT) and assess the effectiveness of MM as an active learning strategy to advance CTSs. It is supposed to be measured by the health sciences reasoning test (HSRT) and then assess the effectiveness of MM as an active learning strategy to advance CTSs.[32] Therefore, critical thinking is essential for care delivery, accurate diagnosis, and treatment, and RTs must acquire excellent skills to meet healthcare demands.

RT is an important and evolving allied healthcare profession requiring critical thinking to care for complex patients. While active learning strategies have shown promise in developing critical thinking in other health students, the effectiveness for RT students remains unclear. MM specifically ties new information to prior knowledge and encourages visualization, important for both constructivist learning and critical thinking. As RT programs aim to prepare competent graduates, exploring the impact of MM on CTSs is justified. This study aimed to address this gap by evaluating whether MM could enhance critical thinking among RT students compared to standard note-taking (SNT).

Materials and Methods

Study design and setting

This quasi-experimental study, as shown in Figure 1, compared the impact of MM versus SNT on RT students' critical thinking over 15 weeks. Students were randomly assigned to the MM or SNT group. Both groups completed pre- and post-tests of critical thinking using the HSRT. The study was conducted in two Saudi Arabian RT programs: King Saud bin Abdulaziz University for Health Sciences in Riyadh and The Batterjie Medical College in Jeddah. The only instrument utilized to gather data was an online survey called the HSRT.

Sampling

The study utilized convenience sampling to recruit participants from two RT programs. Eligible participants were male or female students aged 18 years or older who had never used MM before and were currently enrolled in the RT program. Exclusion criteria included students not in the RT program, those from other universities, non-students, minors, students who had used MM, economically/educationally disadvantaged individuals, illiterate individuals, prisoners, and employee students. Eligible students received an information video via Microsoft Teams explaining the voluntary and confidential nature of participation. Informed consent was obtained digitally. Participants were informed they could withdraw at any time and would be provided results upon request following study completion.

Data collection

All RT students from the two programs received an email from the principal investigator with information about the study and a link to view an informational video. Students who wished to participate submitted consent and HIPAA forms digitally. Participants were then randomly assigned by the PI to either the mind map group (MMG) or standard note-taking group (SNTG) based on the order email responses received, using numbers instead of names. The PI sent initial emails and instructional videos separately to avoid identifying which group students were in. Throughout the 15-week semester, the MMG received mind map training videos and uploaded practice maps, while the SNTG continued regular study. Both groups completed pre- and post-tests online within the given timeframes [Figure 2].

Data analysis

IBM SPSS Version 26 was used to analyze the quantitative data collected from the HSRT assessments. Descriptive statistics characterized participants' critical thinking scores for each group. Inferential statistics addressed the research questions to compare scores between groups. Independent t-tests evaluated differences in mean critical thinking scores between the SNTG and MMG before and after the intervention. Dependent t-tests.

Results

The purpose of this study was to assess the critical thinking abilities of RT students using the HSRT and to analyze how well MM worked as a learning approach to assist students in becoming more adept at critical thinking. Based on group tasks, the total critical thinking scores of the RT students were quantitatively analyzed. Inferential statistics comprised an independent *t*-test to look at

differences in means between groups (MM and SNT) at baseline and after the 16-week intervention (H2, H5).

Upon recruitment, 139 pupils agreed to take part in the study. The allowed time to take the HSRT test was 2 days; however, it was extended to a week due to students' availability issues in the first week of the semester. Of the 139 consenting participants, 42 never took the pre-HSRT, with 97 students taking the pre-HSRT. The MMG consisted of 49 participants, and the SNTG consisted of 48 participants. According to the Insight Assessment (2021) statistical group calculation, "any results wherein the test taker makes an effort less than 60% of the test items or devotes not as much of as 15 minutes on the test are not likely to be valid test attempts," so 11 out of the 97 were automatically excluded. The outcome of the valid pre-HSRT tests was, therefore, 86 (MMG = 46, SNTG = 40).

In the post-HSRT phase of the study, two participants were excluded from the SNTG for not completing the post-HSRT. In addition, five were excluded from the MMG due to the inability to complete the post-HSRT and submit MMs during the study. The result of post-HSRT was 79 participants, resulting in 41 participants in the MMG and 38 in the SNTG. Figure 3 shows the study sample.

Figure 1: Quantitative approach – A quasi-experimental pre-test–post-test design. (Source: Author)

At the pre-HSRT phase of the study (baseline), 86 participants met the inclusion criteria. The participants were third- and fourth-year RT students (45.35%, 54.65%) from the two RT programs in Saudi Arabia. The age span of the RT students is seen in Figure 4, ranging from 20 to 28 years old. The average age was determined to be 21.6, with approximately 40 students being 21 and 23 being 22; this was in line with the average age of Saudi Arabian and American undergraduate students, which is 22.5 and 21, respectively. Study participants were roughly equally distributed in both groups (48.8% male and 51.2% female), which is also representative of the population of RT students in Saudi Arabia.

Out of the 86 students [Figure 5], 21 were in the not manifested category, 44 were weak in critical thinking, 18 had moderate critical thinking, 3 had strong critical thinking, and no superior critical thinking score existed. The distribution reveals that most of the RT students who participated in this study at baseline fell into the poor group, which is indicated by the orange color. Consequently, their total critical thinking score was poor, at 68.3.

Prior to analysis, data were examined to make sure that the requirements for inferential analyses were fulfilled. The aggregate critical thinking scores for both groups were examined for normality assumptions. Since the *P* values for both groups [Table 1] were more than 0.05, which is not statistically significant, it was presumed that the data were regularly distributed. To compare the

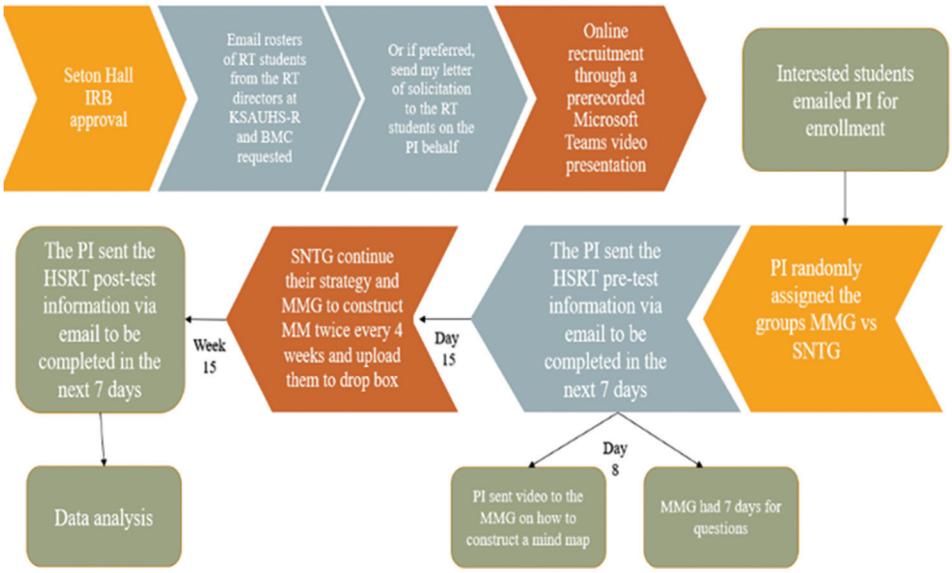

Figure 2: Study process (Source: Author)

MMG (μ = 67.8, SD = 6.2) and SNTG (μ = 68.9, SD = 6.1) pre-test critical thinking scores overall at baseline, an independent *t*-test was used [Table 2]. According to the HSRT, there was no discernible difference between the MMG and the SNTG at baseline in terms of general critical thinking scores ($P = 0.432$). As a result, there was no baseline difference between the two groups.

The MMG post-15-week intervention's overall critical thinking score matched the normalcy assumptions. Since the post-MMG's *P* value [Table 3] was 0.66 and not statistically significant, it was presumed that the data were normally distributed. To compare the MMG's overall critical thinking scores before and after the 15-week MM intervention, a paired *t*-test was piloted. As tested by HSRT in the MMG after 15 weeks of intervention, there was a significant difference between pre (μ = 67.5, SD = 6.3) and post (μ = 70.7, SD = 5.03) overall critical thinking scores [Table 4; $P = 0.02$; Table 5]. The power of the MMG pre- and post-expansion was ascertained using *post hoc* analysis utilizing G*Power software. The power in this category, according to the findings, was 0.81.

The SNTG post-15-week intervention's overall critical thinking score satisfied the expected normalcy assumptions. Since the post-SNTG's *P* value [Table 6] was not statistically significant, it was presumed that the data were normally circulated. After taking standard notes for 15 weeks, the overall critical thinking scores of the SNTGs were compared using a paired sample *t*-test. Table 7 shows that, as determined by HSRT in the SNTG post-15 weeks, there was no significant difference between the pre (μ = 68.9, SD = 6.2) and post (μ = 68.3, SD = 5.4) overall critical thinking scores (*P* value = 0.603, greater than >0.05) [Table 8].

The total critical thinking scores for both groups fulfilled the normalcy assumptions. Since the *P*-values for both groups were more than 0.05 [Table 9] and were not statistically significant, it was also recognized that the data were regularly distributed. The total post-test critical thinking scores between the MMG (μ = 70.7, SD = 5.03) and the SNTG (μ = 68.3, SD = 5.4) post-HSRT were compared using an independent *t*-test [Table 10]. After 15 weeks of intervention, as determined by the HSRT, there was a significant difference ($P = 0.04$) in the overall level of critical thinking scores between the MMG and the SNTG [Table 11].

Discussion

Upon entering the field, respiratory therapists must practice competently and provide evidence-based patient care to address the many respiratory challenges accompanying critically ill patients.[33,34] As part of the healthcare team, respiratory therapists are expected to accurately diagnose, treat, and deliver the best respiratory-related practice protocols to meet healthcare demands.[35] Given the importance of a respiratory therapist as part of the healthcare team, when RT students join the industry, they should be prepared with the critical thinking abilities necessary to address the requirements of critically ill patients and integrate strong evidence-based practices into an interprofessional team.[36] RT academic programs should ensure this.

Respiratory therapists must retain CTSs to apply knowledge precisely and timely.[37] RT academicians

Table 1: Normality assumptions of overall critical thinking scores for both groups

	Kolmogorov–Smirnov[a]			Shapiro–Wilk		
	Statistic	Df	Sig.	Statistic	Df	Sig. (2-sided P)
Pre MMG	0.088	46	0.200*	0.980	46	0.592
Pre SNTG	0.113	40	0.200*	0.954	40	0.101

[a]Lilliefors significance correction

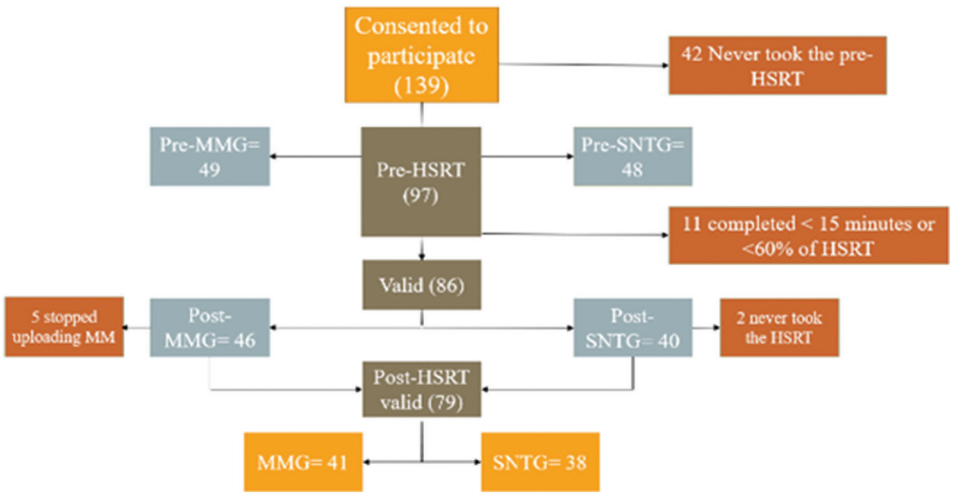

Figure 3: Study sample (Source: Author)

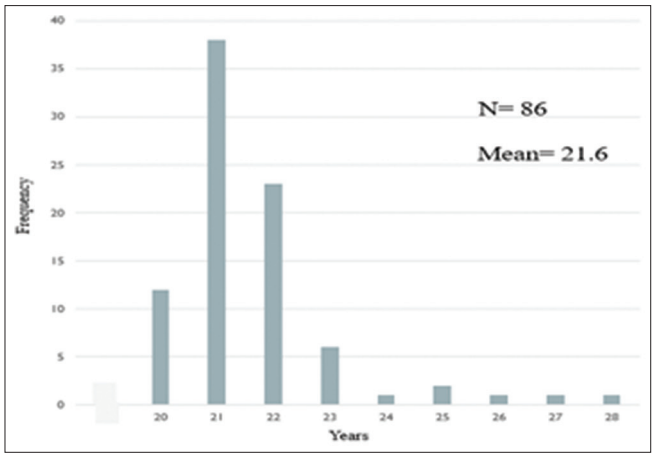

Figure 4: Participants' age. (Source: Author)

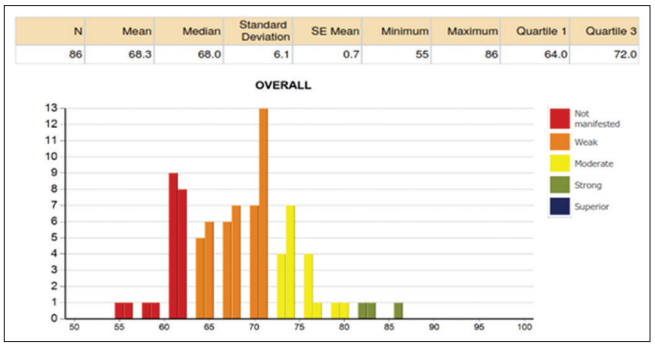

Figure 5: Overall critical thinking scores of RT students at baseline (pre) (Author: Source)

should inculcate learning practices that foster critical thinking and use adult, active learning strategies.[35,38] These strategies can help students to relate, connect, and assimilate information and to progress and implement CTSs. For example, MM—an active learning strategy—practices information organization to assist the analysis, memorization, and understanding of relationships between concepts, leading to creative associations that can boost knowledge acquisition and develop CTSs.[39,40]

In this study, which used the HSRT 100-point scale (newer version), the score can range from the lowest score of 50 to the maximum of 100; the RT undergraduate participants' total critical thinking score was put into the weak category ($\mu = 68.3$). It prognosticates challenges with the demands of reflective problem solving and reflective decision-making that are related to education and work. These results disagreed with those of other studies that assessed RT students' critical thinking abilities using the HSRT instrument.

According to Campbell and Dortch (2018), course designs ought to require students to be challenged to think in ever more complex ways and to create further deep connections with the subjects being studied.[41] Several thoughts emerged in an attempt to understand why the critical thinking scores in the current study and previous studies with RT students were inconsistent. First, all the previous studies were conducted on the US RT student population. In contrast, the current study was conducted on an RT student population from a different country where English is not the primary language. Since RT programs in Saudi Arabia are entirely taught in English and the students take English-as-a-second-language classes during their 4-year bachelor of science program, they are expected to be English-language-proficient. Thus, the authors believed that taking the HRST in English was not an issue. However, language deficiency in a timed test (55 minutes) may have negatively influenced the results and caused additional challenges to the HSRT

Table 2: Group statistics

Group Statistics	Pre-MMG and SNTG	*n*	Mean	Std. deviation	Std. error Mean
Pre-HSRT Overall CTS	Pre-MMG	46	67.83	6.219	0.917
	Pre-SNTG	40	68.88	6.065	0.959

Table 3: Normality assumptions for the MMG Post-15-week intervention's overall critical thinking score

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig. (2-sided P)
Post-MMG CTS	0.088	41	0.200*	0.980	41	0.660

[a]Lilliefors Significance Correction

Table 4: Paired samples statistics

	Mean	*n*	Std. deviation	Std. error mean
Pre-MMG CTS	67.5366	41	6.27733	0.98035
Post-MMG CTS	70.7317	41	5.03996	0.78711

experience. In the study, 65 out of 86 participants fell in the not manifested and weak CTS category. According to the HSRT handbook, these students may have struggled with reading or language comprehension, or they may have been less motivated to study.

It was necessary to ascertain if the sample's age and gender distribution accorded to that of the Saudi RT community, given that there is little to no literature on the critical thinking scores particularly studied on RT Saudi students. The average age of senior Saudi students was 22.5, which is close to the 21.6 average age of third- and fourth-year RT students in the survey. In Saudi Arabia, the segregation of RT gender is comparable to the research group, with 53% of females and 47% of men. As a result, the outcome of the baseline low critical thinking scores was indicative of the RT Saudi students despite the smaller sample size.

After using MM as an improvement technique for 15 weeks, the critical thinking scores from the MMG were compared between the pre- and post-tests to determine if there was a significant difference in the

Table 5: Paired samples test

	Paired Differences					*t*	df	Sig. (2-Sided *P*)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval				
				Lower	Upper			
Pre-MMG CTS- Post-MMG CTS	-3.19	8.14	1.27	-5.76	-0.625	-2.51	40	0.016

Table 6: Tests of normality

	Kolmogorov–Smirnov[a]			Shapiro–Wilk		
	Statistic	Df	Sig.	Statistic	df	Sig.
Post-SNTG CTS	0.124	38	0.145	0.973	38	0.477

Table 7: Paired samples statistics

	Mean	*n*	Std. deviation	Std. error mean
Pre-SNTG CTS	68.9474	38	6.19043	1.00422
Post-SNTG CTS	68.2895	38	5.39724	0.87555

overall critical thinking scores. The pre-HSRT mean was 67.5 (*SD* = 6.3), while the mean in the post-HSRT was 71 (*SD* = 5.03). The findings specified a vivid difference in the total critical thinking scores post 15 weeks of MM intervention as measured by the HSRT (*P* = 0.02). Oliveira *et al*.[42] (2023) stated that these findings differ from D'Antoni *et al*.[43] (2009), who measured the CTS of medical students after a brief exposure to MM (same day) and found no significant difference in overall mean total scores between the MMGs. However, the CTSs of physical therapy students were measured by Israel *et al*.[44] (2020) using the HSRT assessment tool after the introduction of MM as a learning strategy. The researchers observed a significantly affirmative change (a pre-MM HSRT score of 21.4 to a post-MM HSRT score of 23.1) in the students' critical thinking scores, but it was not statistically important. Similarly, Israel *et al*.[9] (2020) observed a positive change (a pre-MM HSRT score of 22.1 to a post-MM HSRT score of 22.8) in the physician assistant students' critical thinking scores, with the majority (61%) of the participants showing an increment in their total CTS post-9-weeks of MM intervention. The current findings are consistent with the literature; when MM was introduced to the students for an extended period, CTSs significantly increased to almost moderate.[23]

After consuming SNT as a learning approach for 15 weeks, the overall critical thinking scores of the SNTG were paralleled between the pre- and post-test to see if there was an evocative difference. The mean values before and after the HSRT were 69 (SD = 6.2) and 68.3 (SD = 5.4), respectively. According to the HSRT, there was no apparent change in the participants' overall critical thinking scores after 15 weeks of MM intervention (*P* = 0.6). The literature and these findings are in agreement. The SNTGs, as previously noted, did not validate a statistically significant amendment in the pre- and post-total critical thinking scores following 15 weeks of SNT, as determined by the HSRT. The SNTG in this study displayed a lower score in the post-HSRT, which might have been initiated by a number of things, such as the test's scheduling, reduced motivation, and greater cognitive tiredness. Furthermore, the students received the post-HSRT during their final exam time, which would have had an unfavorable effect on their readiness, drive, and endurance for the 55-minute test. Nonetheless, the SNTGs' steadiness highlighted how imperative a learning technique is in helping students progress their critical thinking abilities.

The general critical thinking scores of the post-MMG and SNTG were compared to determine if there was a substantial alteration in the overall critical thinking scores between them after 15 weeks of intervention. The post-HSRT mean for the MMG was 71 (*SD* = 5.03), while the mean in the post-HSRT for the SNTG was 68.3 (*SD* = 5.4). The findings indicated a significant difference in the overall critical thinking scores post 15 weeks of intervention between the MMG and SNTG as measured by the HSRT (*P* = 0.04), with the MMG scoring higher at post. Thus, the difference was highlighted when MM was introduced. These findings validate previous research and exhibit the value of mixed-methods instruction (MM) when used over a longer timeframe. This approach assists students in developing the aptitude to nurture critical thinking by keenly participating in their education and acting as lifelong learners. Though note-taking is considered a typical learning approach and does not provide pupils with the depth that MM provides, it is difficult to ignore its advantage over traditional learning techniques like SNT.[45,46]

Conclusion

In conclusion, this study found that MM effectively improved RT students' CTSs over one semester, as measured by HSRT scores, when compared to standard note-taking. It provides initial evidence that MM may be a beneficial active learning strategy for developing this important competency. Further research is still needed to validate these findings across broader populations.

Limitations

The research had limitations, including seven participants not completing the study, subject bias due to self-administered HRST, timing impacting performance, and a convenience sample from two Saudi Arabian RT programs. Despite these, the findings showed MM as an

Table 8: Paired samples test

	Paired Differences					*t*	df	Sig. (2-Sided *P*)
	Mean	Std. deviation	Std. error mean	95% Confidence Interval				
				Lower	Upper			
Pre-SNTG CTS - Post-SNTG CTS	0.657	7.73	1.25	-1.88	3.19	0.524	37	0.603

Table 9: Tests of normality

	Kolmogorov–Smirnov[a]			Shapiro–Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Post-SNTG CTS	0.124	38	0.145	0.973	38	0.477
Post-MMG CTS	0.098	38	0.200*	0.977	38	0.604

*It is a lower bound of the true significance. [a]Lilliefors Significance Correction

Table 10: Group statistics

Group Statistics	Post-MMG and SNTG	*n*	Mean	Std. deviation	Std. error mean
Post-HSRT	Post-MMG	41	70.7317	5.03996	0.78711
Overall CTS	Post-SNTG	38	68.2895	5.39724	0.87555

Table 11: Levene's test and *t*-test

	Levene's Test for Equality of Variances		*t*-test for Equality of Means						
	F	Sig.	*t*	df	Significance, Two-sided *P*	Mean difference	Std. Error Difference	95% Confidence interval of the difference	
								Lower	Upper
Post-MMG and SNTG CTS									
Equal variances assumed	0.347	0.558	2.080	77	0.041	2.44223	1.17425	0.10401	4.78045
Equal variances not assumed			2.074	75.411	0.041	2.44223	1.17734	0.09707	4.78740

effective active learning technique for developing critical thinking abilities in RTs.

Future research directions and implications

Future research could expand the sample size and include additional institutions to improve generalizability and allow for nationwide comparisons. Incorporating other active learning strategies like idea mapping may further support critical thinking. Longer intervention periods, giving students more time to fully develop mind mapping skills, could strengthen results. A mixed methods design may provide richer insight into participants' experiences and better identify limitations. The study established a foundation for understanding how MM impacts critical thinking among RT students in Saudi Arabia. Continued research in this area can help programs foster critical thinking development through strategies like MM. Larger-scale evaluations are needed to fully realize MM's potential benefits in RT education.

Author contributions

Faisal A. Turkestani: Literature search, study design, data collection, analysis of data, manuscript preparation, review of the manuscript; Genevieve P. Zipp: Study design, manuscript preparation, review of the manuscript; Taha Ismaeil: Data collection, review of the manuscript; Saleh S. Algarni: Data collection, review of the manuscript; Ayedh D. Alahmari: Data collection, review of the manuscript. Mazen M. Homoud: Data collection, review of the manuscript; Ziyad F. Al Nufaiei: Analysis of data; Raid Al Zhranei: a review of the manuscript; Fahad Alhadian; Review of the manuscript.

Data availability

The data used to support the findings of this study are available from the corresponding author upon request.

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Conflicts of interest

There are no conflicts of interest.

References

1. Fox RE. Determining the Relationship Between First Time Therapist Multiple Choice Exam High Cut and Clinical Simulation Exam Pass Rates of Recent Respiratory Therapy Graduates From an Ohio University and Their Well-Being and Persistence. Doctoral Dissertations and Projects 2023. Available from: https://digitalcommons.liberty.edu/doctoral/4626.
2. Kacmarek RM, Heuer AJ, Stoller JK. Early history of respiratory care. Egan's Fundamentals of Respiratory Care E-Book. Elsevier Health Sciences; Amsterdam, The Netherlands, 2019. p. 1.
3. Lubken TA. Effect of Professional Exclusion Among Respiratory Therapists in the ICU. Walden University, Washington, USA; 2021.
4. Kacmarek RM, Stoller JK, Heuer AJ. Egan's Fundamentals of Respiratory Care E-Book. Elsevier Health Sciences; 2019.

5. Jaswal P, Behera B. Blended matters: Nurturing critical thinking. E-Learning and Digital Media. 2023;20427530231156184. doi: 10.1177/20427530231156184.
6. Bezanilla MJ, Fernández-Nogueira D, Poblete M, Galindo-Domínguez H. Methodologies for teaching-learning critical thinking in higher education: The teacher's view. Thinking Skills Creat 2019;33:100584.
7. Hickman LA, Neubert S, Reich K. John Dewey between Pragmatism and Constructivism. Fordham University Press, NewYork, USA; 2020.
8. Fatimah S, Rosidin DN, Hidayat A. Student-based learning in the perspective of constructivism theory and maieutics method. Int J Soc Sci Hum Res 2022;5:1632-7.
9. Israel C, Pinto Zipp G, D'Abundo M, Deluca D. Mind mapping to enhance critical thinking skills in physician assistant education: A randomized controlled study. J Allied Health 2020;49:135-40.
10. Intan AS. Improving Students' Speaking Skill by Using Mind Mapping Teaching Media.
11. Lai ER. Critical thinking: A literature review. Pearsons Research Reports 2011;6:40-1.
12. Hamdani SA, Prima EC, Agustin RR, Feranie S, Sugiana A. Development of android-based interactive multimedia to enhance critical thinking skills in learning matters. J Sci Learn 2022;5:103-14.
13. Azizi S, Culp L, Freyberg J, Mustafa B, Baur S, Kornblith S, *et al*. Robust and efficient medical imaging with self-supervision. arXiv preprint arXiv: 2205.09723. 2022.
14. Syawaludin A, Rintayati P. Development of augmented reality-based interactive multimedia to improve critical thinking skills in science learning. Int J Instr 2019;12:331-44.
15. Bryce T, Blown E. Ausubel's meaningful learning re-visited. Curr Psychol 2023:1-20. doi: 10.1007/s12144-023-04440-4.
16. Paul R, Elder L. The Miniature Guide to Critical Thinking Concepts and Tools. Rowman & Littlefield; 2019.
17. Almulla MA, Al-Rahmi WM. Integrated social cognitive theory with learning input factors: The effects of problem-solving skills and critical thinking skills on learning performance sustainability. Sustainability 2023;15:3978.
18. Adams B, Kaczmarczyk AB. Supporting preservice teacher development of culturally responsive reading instruction through a cross-course assignment. Reading Horizons: A Journal of Literacy and Language Arts; 2023;62:3.
19. Djamas D, Tinedi V. Development of interactive multimedia learning materials for improving critical thinking skills. Research Anthology on Developing Critical Thinking Skills in Students. IGI Global, Hershey, Pennsylvania; 2021. p. 507-25.
20. Shaygan M, Yazdani Z, Valibeygi A. The effect of online multimedia psychoeducational interventions on the resilience and perceived stress of hospitalized patients with COVID-19: A pilot cluster randomized parallel-controlled trial. BMC Psychiatry 2021;21:1-12. doi: 10.1186/s12888-021-03085-6.
21. Alhamad BR, Exploring the critical thinking skills of respiratory care students and faculty. Seton Hall University; 2016.
22. Sweet M, Michaelsen LK. Team-based Learning in the Social Sciences and Humanities: Group Work that Works to Generate Critical Thinking and Engagement. Taylor & Francis, United Kingdom; 2023.
23. Mohamed El-Sayed N, Mahmoud Abdel-Azeem A, Khaled Abd El-Aziz Zaki A. The effect of mind mapping on cognitive achievement and critical thinking skills of nursing students. Int Egypt J Nurs Sci Res 2023;3:685-703.
24. Budd S, Robinson EC, Kainz B. A survey on active learning and human-in-the-loop deep learning for medical image analysis. Med Image Anal 2021;71:102062. doi: 10.1016/j.media. 2021.102062.
25. Mueller A, Johnston M, Bligh D. Joining mind mapping and care planning to enhance student critical thinking and achieve holistic nursing care. International Journal of Nursing Terminologies and Classifications; 2002;13:24-7.
26. Ghafar ZN, Lestari A. A critical review of the effectiveness of teaching and learning in higher education. J Soc Sci 2023;2:465-71.
27. Israel C. Does the Use of Mind Mapping as a Learning Strategy by Physician Assistant Students Promote Critical Thinking as Measured by the Health Science Reasoning Test? Seton Hall University; 2019.
28. Saxena H. Enhancing Learning Experience with Augmented Mind Maps. 2022. Available from: https://cris.vub.be/ws/portalfiles/portal/94966867/ThesisHimanshiSaxena.pdf.
29. Tatta J, Willgens AM, Palombaro KM. Mindfulness and acceptance–based interventions in physical therapist practice: The time is now. Phys Ther 2022;102:pzab293. doi: 10.1093/ptj/pzab293.
30. Piggott B, Chivers P, Bulsara C, Conlon J, Grigg K, Harris SA, *et al*. "I'm making a positive change in my life": A mixed method evaluation of a well-being tertiary education unit. Health Promot J Austr 2023;34:518-29.
31. Alsuraihi AA. The effect of implementing mind maps for online learning and assessment on students during COVID-19 pandemic: A cross sectional study. BMC Med Educ 2022;22:1-16. doi: 10.1186/s12909-022-03211-2.
32. Hazaymeh WA, Alomery MK. The Effectiveness of Visual Mind Mapping Strategy for Improving English Language Learners' Critical Thinking Skills and Reading Ability. Eurasian Society of Educational Research, Hanover, USA; 2022.
33. Kinney J. Revisiting the Socratic method of teaching to improve third-year pharmacy students critical thinking and advanced pharmacy practice experience readiness in a critical care elective. Curr Pharmacy Teach Learn 2022;14:499-506.
34. Kacmarek R, Stoller J, Heuer A. Egan's Fundamentals of Respiratory Care E-Book. Elsevier Health Sciences; 2016.
35. Beachey W. Respiratory Care Anatomy and Physiology E-Book: Foundations for Clinical Practice. Elsevier Health Sciences; 2022.
36. Des Jardins T, Burton GG. Clinical Manifestations & Assessment of Respiratory Disease-E-Book. Elsevier Health Sciences; 2023.
37. Willis LD, Rintz J, Zaccagnini M, Miller AG, Li J. Barriers to respiratory care research in the United States. Respir Care 2023;68:1112-8.
38. Quach S, Veitch A, Zaccagnini M, West A, Nonoyama ML. Underrepresentation of respiratory therapists as experts in Delphi studies on respiratory practices and research priorities. Respir Care 2022;67:1609-32.
39. Bizimana E, Mutangana D, Mwesigye A. Enhancing students' attitude towards biology using concept mapping and cooperative mastery learning instructional strategies: Implication on gender. LUMAT Int J Math Sci Technol Educ 2022;10:242-66.
40. Spencer J, Anderson K, Ellis K. Radiant thinking and the use of the mind map in nurse practitioner education. J Nurs Educ 2013;52:291-3.
41. Campbell CM, Dortch D. Reconsidering academic rigor: Posing and supporting rigorous course practices at two research institutions. Teachers College Record 2018 120:1-42.
42. Oliveira B, Fonseca M, Rendas A, Carreiro-Martins P, Neuparth N. A scoping review comparing different mapping approaches pointing to the need for standardizing concept maps in medical education: A preliminary analysis. Knowl Manag ELearn 2023;15:392.
43. D'Antoni AV, Zipp GP, Olson VG. Interrater reliability of the mind map assessment rubric in a cohort of medical students. BMC Med Educ 2009;9:1-8. doi: 10.1186/1472-6920-9-19.
44. Israel C, Pinto Zipp G, D'Abundo M, Deluca D. Mind mapping to enhance critical thinking skills in physician assistant education. J Allied Health 2020;49:135-40.
45. Shi Y, Yang H, Dou Y, Zeng Y. Effects of mind mapping-based instruction on student cognitive learning outcomes: A meta-analysis. Asia Pacific Educ Rev 2023;24:303-17.
46. Al Wafi M, Lisdiana L, Sumarti SS. Development of steam-based human respiratory system teaching materials to improve students' critical thinking skills. J Innov Sci Educ 2022;11:295-304.