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Enhancing Knowledge, Attitude and Behaviour of Lean Healthcare Among Health Science Students: A Quasi-Experimental Study at Oman College of Health Sciences

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Abstract: *Lean Healthcare has emerged as a valuable approach to improving efficiency, reducing waste, and enhancing patient outcomes. However, its integration into health sciences education in Oman remains limited. This study aimed to evaluate the effectiveness of a Lean Healthcare training program in enhancing the knowledge, attitudes, and behaviours of health science students at Oman College of Health Sciences, using the Knowledge–Attitude–Behaviour (KAB) model as the guiding framework. A quasi-experimental one-group pretest–posttest design was employed with a sample of 59 students, predominantly final-year nursing students. Data were collected using a validated questionnaire measuring knowledge (content, training, assessment), attitudes (mindset, leadership), and behaviours (application, feedback, role modelling). Cronbach's alpha confirmed strong reliability across all constructs (α range = .812–.919). Paired-sample t-tests were conducted to examine pre–post changes, and multiple regression was used to identify predictors of post-intervention Lean outcomes. Significant improvements were observed across all domains. Knowledge increased in content ($p < .001$), training ($p < .001$), and assessment ($p = .002$). Attitudes improved in mindset ($p < .001$) and leadership ($p < .001$), while behaviours showed gains in application ($p < .001$), feedback ($p < .001$), and role modelling ($p < .001$). The overall Lean score also improved significantly ($p < .001$). Regression analysis revealed that knowledge was the strongest predictor of post-training Lean outcomes ($\beta = .692$, $p = .001$), while attitude and behaviour were not statistically significant predictors. The intervention successfully enhanced students' Lean-related knowledge, attitudes, and behaviours, with knowledge emerging as the most critical driver of Lean outcomes. These findings underscore the importance of integrating Lean Healthcare training into health sciences curricula in Oman. Embedding Lean principles into education can prepare future healthcare professionals to act as change agents, contributing to efficiency, patient safety, and continuous improvement in healthcare delivery. Further research should employ longitudinal and comparative designs to explore the sustainability of behavioural change and the moderating role of institutional factors such as leadership and organisational culture.*

Keywords: Lean Healthcare; Health Sciences Education; Knowledge–Attitude–Behaviour (KAB) Model; Quasi-Experimental Study; Oman

1. Introduction

Lean principles, originally developed in manufacturing industries, have been increasingly applied in healthcare settings to improve efficiency, quality, and patient outcomes. Lean in healthcare focuses on eliminating waste, improving processes, and enhancing patient value (Fournier et al., 2023). The adoption of Lean in healthcare has gained momentum globally as organisations seek to address challenges in cost-effective care provision (Fournier et al., 2023). Lean in healthcare focuses on eliminating waste, standardising processes, and continuously improving operations to enhance patient care delivery (Prado-Prado et al., 2020). Key aspects of lean in healthcare include: (1) Patient-Centered Care: Placing the patient at the forefront of decision-making and care processes, emphasising their needs, comfort, and outcomes (Prado-Prado et al., 2020), (2) Efficiency and Quality Improvement: Streamlining processes, reducing waste, and standardising workflows to enhance efficiency and quality of care delivery (Prado-Prado et al., 2020), (3) Staff Involvement: Engaging and empowering healthcare staff in process improvement initiatives, fostering a culture of continuous learning and innovation (Prado-Prado et al., 2020), (4) Leadership and Culture: Cultivating leadership support and a culture that values continuous improvement, teamwork, and patient-centric care (Prado-Prado et al., 2020), (5) Training and Development: Providing staff with the necessary knowledge, skills, and tools to implement lean practices effectively (Prado-Prado et al., 2020).

Lean training in healthcare for health science students is crucial for equipping them with valuable skills and knowledge that will be beneficial in their future healthcare careers. These training programs should begin by introducing students to the core principles of lean thinking in healthcare, emphasising concepts such as waste reduction, continuous improvement, patient-centred care, and value stream mapping (Gamaldo et al., 2016). Hands-on learning experiences, such as simulations and case studies, can help students grasp how lean principles can be practically applied in real healthcare settings, enhancing their problem-solving abilities and critical thinking skills (Dinis-Carvalho, 2021). Encouraging interdisciplinary collaboration among students from various health science disciplines can simulate the teamwork required in healthcare improvement projects. Experiential projects that involve analysing processes identifying inefficiencies, and proposing solutions for improvement allow students to apply lean tools and techniques in a practical setting, deepening their understanding of lean concepts. Guest lectures from healthcare professionals who have successfully implemented lean practices and partnerships with healthcare facilities can provide students with valuable insights and practical exposure to lean initiatives (Adam et al., 2021). By integrating lean training into the curriculum for health science students, educational institutions can prepare future healthcare professionals to drive quality improvement, enhance patient outcomes, and contribute to a culture of continuous learning and innovation in healthcare delivery.

Lean training in healthcare is a crucial component of education for Health Science students, offering them a comprehensive understanding of healthcare systems and the principles of waste reduction, continuous improvement, and patient-centred care (Abd Al Fadeel et al., 2023). Through Lean training, students develop essential problem-solving skills, utilising Lean tools like value stream mapping and root cause analysis to identify and address challenges effectively (Hassan Elzohairy et al., 2020). Emphasising patient-centred care, Lean training encourages students to prioritise patient needs and create more efficient and patient-friendly healthcare environments (Mohamed et al., 2023). Furthermore, Lean training promotes teamwork and collaboration among students and healthcare professionals, fostering a culture of shared learning and continuous improvement (Dinis-Carvalho, 2021). By optimising resources, reducing waste, and enhancing operational efficiency, students equipped with Lean knowledge

contribute to cost savings, improved productivity, and better resource utilisation in healthcare settings (Alves et al., 2021). Additionally, Lean training prepares Health Science students for future roles by instilling a mindset of continuous learning and quality improvement, empowering them to drive positive change in healthcare organisations. Aligned with industry trends focusing on quality, safety, and efficiency in healthcare, Lean training ensures that students are well-prepared to meet the evolving demands of the healthcare sector (Aljazzazen and Schmuck, 2021). Overall, lean training in healthcare plays a vital role in shaping competent and quality-focused healthcare professionals who are ready to make a positive impact in the healthcare industry.

Despite the growing emphasis on quality improvement and efficiency in healthcare delivery, there is a gap in the integration of Lean Management training within the curriculum, leading to potential challenges in optimising healthcare processes and enhancing patient outcomes (Al Farsi et al., 2014). This gap highlights the necessity for a structured intervention that focuses on enhancing students' knowledge, attitude, and behaviour towards Lean Healthcare practices to better prepare them for the evolving healthcare landscape in Oman(Sohal et al., 2021). In the context of healthcare education at Oman College of Health Sciences, there is a recognised need to improve the understanding, mindset, and practical application of Lean Healthcare principles among Health Science students. Health Science students in Oman exhibit knowledge gaps regarding Lean principles and practices in healthcare, coupled with limited awareness of the benefits of Lean methodologies in improving patient outcomes and operational efficiency (Mehdi and Al Bahrani, 2017). This lack of knowledge and positive attitudes towards Lean in healthcare settings hinders the adoption of Lean practices and the implementation of quality improvement initiatives among future healthcare professionals in Oman (Sohal et al., 2021). Without a solid understanding of Lean methodologies, students may struggle to identify inefficiencies, optimise processes, and enhance patient care in alignment with Lean principles (Al Farsi et al., 2014). The attitudes of Health Science students towards Lean in healthcare play a crucial role in shaping their willingness to embrace Lean practices and drive continuous improvement (Salubi et al., 2022). Positive attitudes towards Lean can foster a culture of quality improvement and innovation in healthcare organisations (Salubi et al., 2022). The behaviour of Health Science students in Oman regarding Lean training and implementation is influenced by their knowledge and attitudes towards Lean in healthcare (Fournier et al., 2021). Without adequate knowledge and positive attitudes towards Lean, students may not actively engage in Lean training programs or apply Lean principles in their future healthcare roles. Hence, the research aims to answer the following questions: How does Lean training impact the knowledge, attitudes, and behaviors of Health Science students in Oman, and what are the implications for integrating Lean principles into healthcare education to improve patient outcomes and operational efficiency?

Research Objectives

The objectives of this research are:

- To assess the effectiveness of implementing Lean training in healthcare education for Omani Health Science students based on the Knowledge, Attitude, and Behavior (KAB) model
- To enhance students' readiness to apply Lean principles in future healthcare practice.

Research Significance

Conducting research on the implementation of Lean training in healthcare for Omani Health Science students based on the Knowledge, Attitude, and Behavior (KAB) model holds significant implications across various domains. This research has the potential to enhance the curriculum of Health Science programs in Oman, fostering essential skills for process

improvement and patient-centred care. By understanding the impact of Lean training on students' knowledge, attitudes, and behaviours, strategies for continuous professional development can be informed, leading to improved healthcare quality, patient safety, and operational efficiency. Moreover, the findings can influence healthcare policies, contribute to the existing knowledge on Lean implementation, and offer practical insights for designing effective Lean training programs tailored to the needs of future healthcare professionals in Oman, ultimately driving positive change in the healthcare system.

2. Literature Review

Theoretical background Knowledge-Behavior-Attitude (KAB) Model

In the research study focusing on Lean Healthcare implementation among Health Science students at Oman College of Health Sciences, a comprehensive framework based on the Knowledge-Behavior-Attitude (KBA) model is proposed. The KBA model encompasses three key dimensions essential for understanding and promoting Lean principles within the healthcare context.

Firstly, the Knowledge (K) Dimension pertains to the students' understanding and awareness of Lean Healthcare principles, tools, and practices. Rooted in cognitive learning theories, this dimension emphasises the significance of acquiring knowledge as a precursor to behavioural change. Essential concepts such as waste reduction, continuous improvement, and patient-centred care form the core of Lean Healthcare knowledge (Abd Al Fadeel et al., 2023).

Secondly, the Behavior (B) Dimension focuses on the actions and practices demonstrated by students when applying Lean Healthcare principles in real-world scenarios. Drawing from behavioural theories like the Theory of Planned Behavior and Social Cognitive Theory, this dimension underscores the role of individual beliefs, self-efficacy, and social influences in shaping behaviour. Practical application through simulations, case studies, and role-playing exercises is crucial for translating knowledge into actionable skills (Fournier et al., 2021).

Thirdly, the Attitude (A) Dimension reflects students' perceptions, beliefs, and feelings towards Lean Healthcare practices and their impact on healthcare delivery. Grounded in attitude formation theories, this dimension highlights the interplay of emotions and cognitive evaluations in shaping attitudes. To foster positive attitudes towards Lean principles, interventions should emphasise the benefits of efficiency, quality improvement, and patient safety through engaging activities and reflective discussions (Fournier et al., 2021).

The integration of the KBA model in the research framework establishes vital links between knowledge, behaviour, and attitude. Enhancing knowledge serves as a foundation for initiating behaviour change, as students must grasp the underlying rationale of Lean principles to effectively apply them in healthcare settings. Engaging in hands-on activities can influence attitudes towards continuous improvement and teamwork, thereby reinforcing positive perceptions of Lean Healthcare. Moreover, positive attitudes can motivate students to seek further knowledge and skill development, creating a cyclical process of continuous learning and improvement (Fournier et al., 2021).

Knowledge related to lean in healthcare

Knowledge transfer is crucial in Lean Healthcare, as employees express gratitude for acquiring new knowledge through Lean projects, emphasising the importance of knowledge acquisition in shaping attitudes and behaviours (Fernandes et al., 2020). This involves understanding the

principles and tools of Lean Healthcare, encompassing specific content, training received, and the assessment of that knowledge (Fernandes et al., 2020). Content refers to the information, theories, and principles that individuals need to comprehend, while training involves providing individuals with the necessary skills and knowledge through structured learning programs (Prado-Prado et al., 2020) and providing medical students with a thorough understanding of Lean principles, tools, and methodologies relevant to healthcare settings (Al Khamisi et al., 2019). Assessment evaluates individuals' understanding and proficiency in applying the knowledge they have acquired. Leaders play a vital role in knowledge transfer to team members regarding Lean principles, tools, and problem-solving techniques (van Elp et al., 2022). Assessments provide tools for continuous evaluation of students' knowledge through quizzes, exams, and practical projects to confirm their proficiency in Lean principles and their application in healthcare (Al Khamisi et al., 2019). Training and education on Lean methodologies are essential for building the necessary knowledge base within teams to effectively drive Continuous Improvement (CI) initiatives (van Elp et al., 2022). Training is done through Delivering structured educational sessions, workshops, and case studies focusing on Lean concepts like waste reduction, process optimisation, and patient-centred care (Al Khamisi et al., 2019). Based on the previous, the research postulates the following hypotheses:

H1a: The content of the Lean Healthcare training program significantly enhances participants' knowledge of Lean principles.

H1b: The method of training delivery in Lean Healthcare positively influences participants' knowledge of Lean principles.

H1c: The assessment methods used for Lean Healthcare intervention reveal a significant improvement in participants' knowledge levels.

H1: Participants with higher baseline knowledge of Lean Healthcare concepts demonstrate better performance and application during the training program.

Attitude related to lean in healthcare

Attitude in Lean Healthcare encompasses mindset, organisational culture, and leadership approaches towards change, influencing the adoption of Lean principles and practices (Fernandes et al., 2020). Leaders play a crucial role in sharing responsibility for problem-solving with team members and creating an environment conducive to Continuous Improvement (CI) activities (van Elp et al., 2022). The mindset of leaders significantly impacts the culture of continuous improvement within healthcare teams undergoing Lean Management initiatives, with transformational leadership behaviours fostering innovation, critical thinking, and employee engagement (Erthal et al., 2021). To cultivate a positive attitude towards continuous improvement, teamwork, and patient safety, it is essential to highlight the benefits of Lean in enhancing healthcare quality. Fostering a culture of innovation, collaboration, and open communication among medical students can encourage a shared commitment to Lean principles. Developing leadership qualities in students aligned with Lean values, such as problem-solving and data-driven decision-making, is crucial for instilling a culture of continuous improvement and patient-centered care (Prado-Prado et al., 2020). Hence, the research postulates the following hypotheses:

H2a: Omani students with a positive and receptive mindset towards Lean Healthcare are more likely to actively engage in learning and effectively apply Lean principles during the intervention program.

H2b: Omani students coming from a culture that values teamwork, continuous improvement, and efficiency are more likely to embrace and integrate Lean Healthcare principles into their professional practices during the intervention program.

H2c: Effective leadership within the intervention program, characterised by mentorship, empowerment, and role modelling of Lean principles, positively influences Omani students' leadership capabilities in driving Lean Healthcare transformations.

H2: Omani students with positive attitudes towards Lean principles are more inclined to accept, endorse, and effectively implement Lean Healthcare practices as part of their training experience.

Behaviour related to lean in healthcare

Behaviour in Lean Healthcare implementation involves the practical application of knowledge, receiving constructive feedback, and role modelling by leaders and colleagues (Fernandes et al., 2020). The continuous improvement mindset promoted by Lean practices encourages employees to constantly seek better results and effectively apply new knowledge in their work environment. Leadership styles, including transformational and transactional behaviours, influence team dynamics and the maturity levels of Continuous Improvement (CI) within healthcare organisations (D'Andreamatteo et al., 2019; Erthal et al., 2021). Encouraging medical students to apply Lean principles in real-world healthcare scenarios, providing constructive feedback on their performance, and showcasing successful examples of Lean implementation can inspire a culture of continuous improvement and operational efficiency van Elp et al., 2022). By integrating hands-on projects, simulations, and internships, students can develop the skills necessary for identifying improvement opportunities and implementing Lean practices effectively (Prado-Prado et al., 2020). Hence, the research postulates the following hypotheses:

H3a: Omani students who actively apply Lean Healthcare principles in real-world scenarios during the intervention program demonstrate a deeper understanding and better retention of Lean concepts

H3b: Omani students who receive constructive feedback on their performance in Lean Healthcare practices during the intervention program show increased motivation and enhanced capabilities in implementing Lean principles effectively.

H3c: Omani students who observe positive role models showcasing effective implementation of Lean Healthcare practices during the intervention program are more likely to emulate similar behaviours and actions, leading to improved adoption and application of Lean principles in their own practice.

H3: Omani students whose behaviours are closely aligned with Lean principles demonstrate higher success rates in implementing Lean practices in healthcare settings.

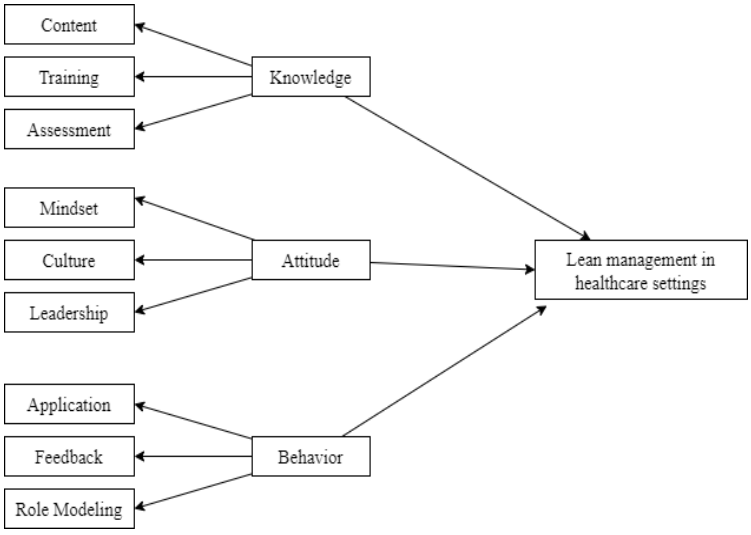

Figure 1: Conceptual framework

3. Methodology

Research Design: A one-group pretest-post-test design will be utilised to evaluate the impact of the Lean Healthcare training intervention. This design involves measuring the same dependent variables in a single group of participants both before (pretest) and after (post-test) the administration of the training intervention.

Population and Sample: The target population for this study includes undergraduate and graduate students enrolled in health science programs at Oman College of Health Sciences. Participants will be selected using a purposive sampling technique based on specific criteria related to their enrolment in health science programs and willingness to participate in the study. The sample size is calculated using G power sampling using a difference in means between pre-and post-intervention results in one sample group with α error = 0.05 and power (1-β error prob) =0.95. The total sample size based on G* power sampling is 45

Research Instrument: A research instrument is a survey that is developed to assess students' knowledge, attitude, and behaviour towards Lean Healthcare. The instrument will include items that measure baseline understanding of Lean Healthcare concepts and attitudes towards its implementation. Survey Items related to knowledge related to Lean management in healthcare settings are adopted from (D'Andreamatteo et al., 2019; Erthal et al., 2021; Hassan Elzohairy et al., 2020; Prado-Prado et al., 2020; Veres et al., 2021) for the content variable, (Abd Al Fadeel et al., 2023; Al Khamisi et al., 2019; Aljazzazen and Schmuck, 2021; Hassan Elzohairy et al., 2020; Mohamed et al., 2023) for assessment variable, (Akmal et al., 2022; Fernandes et al., 2020; Fournier and Jobin, 2018; Naidoo and Fields, 2019; Salubi et al., 2022) for training variable. Survey items for behaviour related to Lean management in healthcare settings are adopted from (Fournier et al., 2023; Gamaldo et al., 2016; Parkhi, 2019; Prado-Prado et al., 2020; Veres et al., 2021) for the application variable, (Akmal et al., 2022; Erthal et al., 2021; Fernandes et al., 2020; Fournier et al., 2021; van Elp et al., 2022) for the Feedback variable, (D'Andreamatteo et al., 2019; Fernandes et al., 2020; Fournier and Jobin, 2018; Machado et al., 2015; Mohamed et al., 2023) for role modelling variable. Survey items for Attitude related to Lean management in healthcare settings are adopted from (Abd Al Fadeel et al., 2023; Al Khamisi et al., 2019; Aljazzazen and Schmuck, 2021; Hassan Elzohairy et al., 2020; Salubi et al., 2022) for the Mindset variable, (Erthal et al., 2021; Fournier et al., 2021; Parkhi, 2019) for culture variable, (Erthal et al., 2021; Prado-Prado et al., 2020) for leadership variable. Lean management in healthcare settings survey items are adopted from (Fournier et al., 2021; Naidoo and Fields, 2019; Parkhi, 2019). The survey is presented in Appendix A.

The data collection method involves three main stages:

a) Pre-Intervention Assessment:
Before implementing the Lean Healthcare intervention, the research instrument is administered to the participants. The research instrument will be used to gather information on students' current knowledge levels, attitudes towards Lean Healthcare, and behaviours related to its application. Data collected during this stage provides a baseline understanding of the students' starting point in terms of their familiarity with Lean Healthcare concepts and their readiness for the intervention.

b) Intervention Implementation:
The Lean Healthcare Training intervention is then conducted following a standardised approach focusing on Lean Healthcare principles and practices. The intervention will be delivered consistently to all participants to maintain uniformity in the learning experience and the information provided.

c) Post-Intervention Assessment:
After the completion of the Lean Healthcare Training intervention, the research instrument is re-administered to the students. The purpose of this post-intervention assessment is to measure any changes in students' knowledge, attitudes, and behaviours regarding Lean Healthcare following their participation in the intervention. A comparison is made between the data collected before and after the intervention to evaluate the effectiveness of the intervention in enhancing students' understanding and application of Lean Healthcare principles.

4. Results

4.1 Demographic Characteristics of Participants
In total, the sample consisted of 59 students from Oman College of Health Sciences. The sample was predominantly female (n = 45, 76.3%) with the proportion of males being much smaller (n = 13, 22.0%). Almost all of them were final-year students (n = 58, 98.3%) with only one representing a first-year student (1.7%). The sample was overwhelmingly composed of students from the nursing program (n = 56, 94.9%) with only a few students from the medical program (n = 3, 5.1%).

Concernig previous exposure, no participant claimed any type of formal education in Lean management before the intervention. Self descriptions of the baseline Lean knowledge level were generally poor. Almost 40% consider themselves a level 1 or 2 on a 5 level scale and less than 20% confident enough to describe themselves as highly familiar (levels 4-5). Due to such prior knowledge, the greater part of the sample had interest in receiving Lean training. More than 88% of the respondents were ready to engage with Lean in the context of health care while almost all respondents, 94.9% agreed on the conclusion that Lean could enhance the efficiency and patient outcomes of clinical practice. This suggests that the sample had interest in the intervention while also having lack of knowledge in the area.

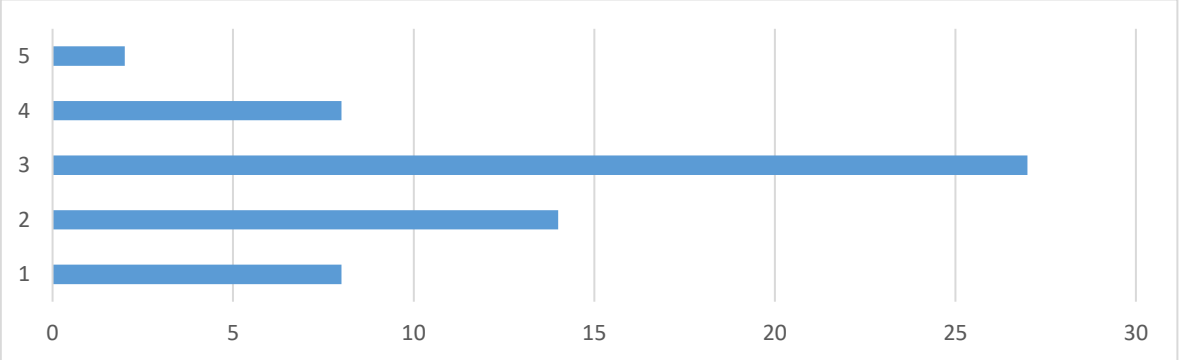

Figure 2: Distribution of students' self-reported familiarity with Lean management concepts at baseline (N = 59).

4.2 Measurement Scale Reliability
Before any specific testing of hypotheses, the measurement tool's internal consistency was assessed using Cronbach's alpha. Every measurement was exceptionally dependable, each

surpassing the benchmark of 0.70. Subscales of knowledge content (α = 0.865), training (α = 0.919), and assessment (α = 0.882) were all exceptionally dependable. The attitude-related dimensions were also strong, with mindset (α = 0.812) and leadership (α = 0.904) strong. Likewise, high-reliable behavioural dimensions such as application (α = 0.826), feedback (α = 0.882), and role modelling (α = 0.856) were recorded. Results are demostrated in Table 1. The total Lean scale also proved reliable with an alpha of .879. These scores indicate that the instrument in question was strong and appropriate for determining the alterations in the knowledge, attitude and behaviour gained after undergoing the Lean Healthcare training. The high levels of reliability shown for the instrument also attests the level of validity that can be attributed to the Knowledge–Attitude–Behaviour (KAB) model for this context.

Table 1: Measurement Scale Reliability

Construct	Cronbach's Alpha	Number of Items	Interpretation
Content	0.865	5	High internal consistency; items measuring Lean content knowledge are reliable.
Training	0.919	5	Excellent reliability; training-related items are strongly consistent.
Assessment	0.882	5	High reliability; assessment items accurately reflect knowledge evaluation.
Mindset	0.812	5	Good reliability; items measuring students' mindset towards Lean are consistent.
Leadership	0.904	5	Excellent reliability; strong coherence among leadership attitude items.
Application	0.826	5	Good reliability; items consistently capture students' application of Lean.
Feedback	0.882	5	High reliability; feedback-related items demonstrate strong consistency.
Role Modelling	0.856	6	High reliability; items consistently reflect role-modelling behaviours.
Overall Lean	0.879	4	High reliability; overall Lean construct is strongly measured.

4.3 Knowledge, Attitude and Behaviour Comparison Before and After the Training

In measuring the effectiveness of the Lean Healthcare training program, participants' scores all pertaining to knowledge, attitude and behaviour were recorded and compared before and after the intervention to determine the effectiveness of the training using paired sample t-tests. Results showed positive gains in all areas assessed, indicating that the training was successful. The participants' Knowledge was measured using content, training, and assessment subscales. All three areas showed significant improvements. For content, the post intervention score was significantly higher than the baseline score (M difference = –0.69, SD = 1.17, $t(48) = –4.13$, $p < .001$). Similarly, training-related knowledge increased to a meaningful degree (M difference = –0.56, SD = 1.02, $t(48) = –3.83$, $p < .001$). Even assessment-related knowledge increased (M difference = –0.49, SD = 1.02, $t(48) = –3.32$, $p = .002$). All these results pointed to the fact that the participants' understanding of the Lean principles improved due to the ways in which the training materials were presented, how the training was delivered, and how participants were assessed.

Attitudes were evaluated focusing on the mindset and leadership parts. Both subscales showed significant positive growth. For mindset, the results indicated that students were more willing to embrace, adopt, and implement Lean practices, and were more positively inclined to be open to the new ways of thinking and changes (M difference = –0.63, SD = 0.85, $t(48) = –5.18$, $p < .001$). Leadership attitudes were also positively shifted (M difference = –0.59, SD = 1.06, $t(48) = –3.88$, $p < .001$) which showed that respondents believed more than before about the

importance of robust leadership to foster the effective use of Lean. The outcome means not only an increased understanding on the topic, but a cultural shift towards Lean thinking as well. Behavioral change was measured via application, feedback, and modelling of change. Once again, substantial gains were noted in all areas. The practice of Lean techniques also showed very positive improvement (M difference = –0.57, SD = 0.99, t(48) = –4.05, p < .001) which indicates that students were more willing to incorporate Lean tools in their workflows. Feedback behavior also improved (M difference = –0.61, SD = 1.07, t(47) = –3.93, p < .001) which shows that students became more willing to accept and utilize constructive feedback. Role modelling also showed positive results (M difference = –0.60, SD = 1.08, t(47) = –3.85, p < .001) which shows that students were more likely to engage in Lean behavior and act as peer role models.

Considering these as a single construct, overall Lean scores also improved significantly from pre-test to post-test (M difference = –0.79, SD = 1.14, t(47) = –4.82, p < .001). These scores reflect the comprehensive effectiveness of the intervention on the participants' perception, attitude, and action.

Table 2: Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	PRE_CONTENT - POST_CONTENT	-.68878	1.16634	.16662	-1.02379	-.35376	-4.134	48	.000
Pair 2	PRE_TRAINING - POST_training	-.55918	1.02137	.14591	-.85256	-.26581	-3.832	48	.000
Pair 3	PRE_Assessment - POST_Assessment	-.48571	1.02307	.14615	-.77957	-.19186	-3.323	48	.002
Pair 4	PRE_MINDSET - POST_Mindset	-.62653	.84700	.12100	-.86982	-.38324	-5.178	48	.000
Pair 5	CSA_PRE - CSA_POST	.42935	.95694	.14109	.14517	.71352	3.043	45	.004
Pair 6	PRE_LEADERSHIP - POST_Leadership	-.58673	1.05942	.15135	-.89104	-.28243	-3.877	48	.000
Pair 7	PRE_APPLICATION - POST_APPLICATION	-.57143	.98742	.14106	-.85505	-.28781	-4.051	48	.000
Pair 8	PRE_FEEDBACK - POST_FEEDBACK	-.60938	1.07365	.15497	-.92113	-.29762	-3.932	47	.000
Pair 9	PRE_ROLE - POST_ROLE	-.60139	1.08244	.15624	-.91570	-.28708	-3.849	47	.000
Pair 10	PRE_LEAN - Post_Lean	-.79132	1.13720	.16414	-1.12153	-.46111	-4.821	47	.000

Understanding Changes Before and After the Implementation

The results have shown that the implemented approach increased the Lean knowledge, attitudes and behaviours of the participants. The knowledge increases demonstrate the efficacy of the materials as well as the training structure and design. The positive terrain garnered attitudes especially on mindset and leadership indicate that the training was successful in fostering some framework

openness to the cultural and organisational change. Improvements on the behavioural measures of application, feedback, and role modelling to say that the students not only learned Lean concepts, but also were actively engaging in the doing of Lean practices.

The findings on all the measures suggest the training program is well designed and the changes in behaviour in particular suggest that students will assume Lean change agent responsibilities in the and they will practice the objectives of the health science program which is to prepare graduates to be change leaders for the quality improvement of the Health Care System in Oman.
4. Regression Analysis. Predicting Lean After the Intervention Outcomes

Multiple regression analysis was done to find the best predictors of Lean outcomes post the intervention. The post intervention Lean score was used as the dependent variable and knowledge, attitude and behaviour were used as independent the predictors. Model Summary Statistical analysis revealed the model to be significant as it indicated $F(3, 45) = 28.62$, $p < 0.001$, thus establishing the model helps outcome appreciated changes for post intervention lean model operations. Additionally, the model correlated outcome variance/intervention lean changes as 65.5% (R squared 0.655 adjusted R squared 0.630) showcasing strong predictive value. Hence, the model performed well to predict variance-model post training changes.

Predictor analysis revealed the outcome lean scores. Otherwise, knowledge proved to be the strongest as well as the strongest post intervention predictor. It was found that the outcome knowledge metric was Lean based ($\beta = 0.692$, $t = 3.71$, $p = 0.001$) thus those students who performed better in the Lean metric posses the greater outcome knowledge metric.

Attitude and behaviour proved to be the weakest and most non significant as post intervention lean scores ($\beta = –0.002$, $t = –0.017$, pat $= 0.987$) and ($\beta = 0.140$, $t = 0.855$, $p = 0.397$) respectively. Further, they based predominately positive scores and lean outcome behaviors thus students scored more positive than average post outcomes on behaviour who scored positive outcomes on lean outcomes from knowledge gained so they posses positive knowledge about lean.

Table 3: Model Summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.809[a]	.655	.630	.54668

a. Predictors: (Constant), BEHAVIOUR, ATTITUDE, KNOW

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.251	.617		-.407	.686
	KNOW	.919	.248	.692	3.708	.001
	ATTITUDE	-.005	.269	-.002	-.017	.987
	BEHAVIOUR	.174	.203	.140	.855	.397

a. Dependent Variable: Post_Lean

These outcomes reinforce the essence of knowledge in influencing the Lean outcomes of the health science learners. While attitudes and behaviours are necessary for practical application, in this case, their influence seems to be hidden behind knowledge. This is consistent with the

KAB model that this study is based on, where knowledge contributes to the change of attitudes and practices.

The non-significant effects of attitude and behaviour warrant careful interpretation. It is possible that the short duration of the intervention limited the extent to which attitudinal and behavioural changes could independently influence Lean outcomes. Alternatively, improvements in these areas may require longer-term reinforcement and practice before translating into measurable outcomes. This suggests that while students demonstrated immediate gains in openness and behavioural intentions, sustained exposure and experiential learning may be necessary for these constructs to emerge as significant predictors in future studies.

5. Discussion

This study aimed to determine the effectiveness of a Lean Healthcare training program for students of health sciences in Oman. The training program's success was predicted by the Knowledge–Attitude–Behaviour (KAB) model. Results indicated substantial progress in all three areas. Knowledge of Lean concepts improved. Students' attitudes shifted more positively, especially in the areas of mindset and leadership. Their application behaviours, feedback behaviours, and role modelling behaviours improved. Regression analysis also showed that knowledge was the best predictor of overall Lean outcomes after an intervention and the dominant variable in the students' performance.

These results underscore the importance of training in Lean thinking to health sciences students in regard to the future professional responsibilities, and they support the theoretical underpinnings of the KAB model: attitudinal and behavioural change is driven by the change in underlying knowledge.

5.1 Knowledge Improvement from Lean Training

The enhancements in knowledge were observed in all three subdomains within the content, training, and assessment framework. The importance of these results is that they demonstrate the effectiveness of training programs in improving cognitive familiarity with the concepts of Lean. This finding is in agreement with previous studies that showed the absence of knowledge is a barrier in the adoption of Lean in healthcare (Fernandes et al., 2020; Prado–Prado et al., 2020).

In the current case, the outcomes may have resulted from the use of customized educational materials and structured assessments. Prior research suggests that practical and interactive Lean training promotes enhanced understanding and retention (Al Khamisi et al. 2019). The outcomes also align with those of Hassan Elzohairy et al. (2020) who indicated that training focused on Lean concepts improved appreciation of quality and safety of the participants.

Surprisingly, in the regression model, knowledge was the only significant predictor of post-training Lean performance. This points to the importance of knowledge in the short term achievement of Lean outcomes. While there were significant descriptive gains in attitudes and behaviours, these were not in isolation predictors of the overall Lean outcomes. This implies that mastery of the principles of Lean enough to sustain change in behaviour is a gateway. This has also been pointed out by Alves et al. (2021) who argue that Lean education provide the knowledge base from which subsequent change in attitude and culture can be influenced.

5.2 Shifts in Attitudes towards Lean Principles

The study also demonstrated a change in attitude, particularly in the domains of mindsets and leadership skills, beyond the attainment of knowledge. The students were able to appreciate Lean better as a framework for enhancing efficiency in healthcare delivery and patient care, and they expressed greater confidence regarding the role of leadership in Lean Implementation. The change in attitude is consistent with other work which has shown that mindset and leadership are crucial in fostering a culture of Lean in healthcare organisations (Erthal et al., 2021; Salubi et al., 2022). Mindsets that are positive and fostered at the right levels will help reduce attitude barriers, and a leadership that is willed and willing will indicate the preparedness of the organisation to engage in Lean as described by (van Elp et al., 2022).

The results also corroborate previous studies that stressed the significance of incorporating Lean education at early stages of learners' professional socialization to promote a culture of efficiency and patient centered care (Mohamed et al., 2023). With the right attitude, students can be prepared to act as change agents to healthcare systems that are resistant to Lean as described by (Akmal et al., 2022).

Nonetheless, the attitude measure did not independently explain post-training Lean outcomes as captured in the regression outcomes. This demonstrates that attitudes are likely critical for sustainability over the long term, although their impact may take time before measurable manifestations are detected. Unlike knowledge, the formation of attitudes take time and may require practice as well as (real-life) deployments in order for the impact of the attitude to be fully realized (Fournier et al., 2021).

5.3 Application, Feedback and Role Modelling: Improvements in Behaviours

There were also notable improvements in behaviours as a result of the training intervention, especially with regards to application, feedback, and role modelling. Students demonstrated increased willingness to apply Lean techniques to their daily work, access and act on feedback, and practice Lean behaviours for their peers. These outcomes support the claims made by Fournier and Jobin (2018) as well as Prado-Prado et al. (2020) that learning by doing is vital for the application of Lean principles.

In particular, role modelling demonstrated more than usual improvement, suggesting that students not only learned Lean behaviours, but also started to think of themselves as future proponents for the adoption of Lean. Previous work demonstrated the value of role modelling in helping integrate Lean techniques into teams in the healthcare sector (Machado et al., 2015; van Elp et al., 2022).

Regardless, the behavioral gains did not emerge as independent predictors in the regression model. One reason could be that the length of the study period was too limited for the possible behavioral change to emerge as a central element. As D'Andreamatteo et al. (2019) pointed out, Lean adoption in the healthcare sector, like in many other sectors, takes a considerable amount of time to change behavior permanently due to the need for substantial reinforcement and support from the system.

The outcomes in this study support the claim that behavioral gains can be achieved from a focused training program. However, this study also contends that the gains would be sustainable if there is a system of mentoring, practice, and feedback that is not just in the training environment.

6. Conclusion

The study was conducted to assess the effectiveness of the Lean Healthcare training program among the students of the Oman College of Health Sciences. The analytical approach KAB model served to study the outcomes of this approach. The results achieved were significantly positive in all areas associated with the training.

Knowledge was gained at all the levels of content, training, and assessment. The attitude gained was positive in the aspects of mindset as well as leadership, and the associated behaviors strengthened concerning application, feedback, and role modeling. The results also suggested that the regression analysis confirmed that knowledge was the strongest predictor of all outcomes, therefore underpinning the outcomes as Lean was likely to enable a favorable shift in attitude and behavior.

These results validate the importance of incorporating Lean Healthcare instructiion into the health sscines curricula. If educational institutions arm students with the knowledge, attitudes, and behaviours required to implement Lean principles, the institutions will help in addressing Oman's health care needs by enhancing the capacity to improve efficiencies, reduce waste, and improve patient care.

Practical Implications

The research has numerous implications for the education and practice of healthcare. First, the principles of Lean must be taught in all health sciences courses so that students can be competent and practice as health professionals. It has been evidenced that learning Lean at early stages of training increases the chances of successful implementation at the workplace (Al Khamisi et al., 2019; Alves et al., 2021). Second, training resources should go beyond the standard lectures and focus on active and experiential learning, more especially the use of practice, simulations and role plays, to accentuate positive behaviours (Prado-Prado et al., 2020). Third, students should be prepared to assume Lean leadership positions as this area was shown to improve the most in this study, and leadership is crucial to the organisational readiness for Lean (van Elp et al., 2022). Finally, the results of the study should help the Ministry of Health and the higher education of Oman policymakers in the country by providing insight on the need for Lean principles to be integrated into workforce development policies (Sohal et al., 2021).

Limitations

There remain some limitations to the current study. First, the study was conducted with a one-group pre–post design and control was lacking. This design is said to have a weaker capacity for causal inference than other designs. Second, the sample was taken from a single institution and consisted, almost exclusively, of final year students in a nursing program. This narrow approach restricts generalisability a great deal. Third, the assessments for behaviour change were conducted sometime after the intervention, and no assessments were made at longer intervals to see what the longer-term effects were. Any discussions about the results include these factors. Equally, they need to be taken into account in any further research conducted in this area.

Recommendations and Future Research Directions

Future research should seek to expand the diversity of participants by including students from multiple institutions and disciplines, thereby improving generalisability and examining potential variations across professional tracks. Longitudinal designs would be especially

valuable, as they could follow students beyond graduation to assess how Lean knowledge, attitudes, and behaviours translate into workplace practices and ultimately impact patient outcomes (Fournier et al., 2021). Employing comparative designs such as randomised controlled trials or quasi-experiments with control groups would also strengthen causal inference about training effectiveness. Moreover, future studies should investigate the role of institutional factors, such as organisational culture and leadership support, which are likely to moderate the effectiveness of Lean training in clinical settings (Erthal et al., 2021). Finally, researchers should explore mechanisms for sustaining behavioural change over time, for instance by examining how mentorship, peer feedback, and continuous assessment might reinforce Lean-consistent practices in healthcare environments.

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Conflict of Interest Statement
The authors declare that there is no conflict of interest regarding the publication of this study.

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Appendix A

The survey conducted at Oman Health Sciences College assesses the impact of Lean Healthcare intervention on students' knowledge, attitudes, and behaviours towards Lean methodologies in healthcare. By analysing pre- and post-intervention data using statistical methods like paired t-tests and ANOVA, the study aims to evaluate the effectiveness of the intervention in enhancing students' understanding and application of Lean principles. The research seeks to uncover insights that can lead to improved educational experiences, skill development, and the promotion of a culture of continuous improvement in healthcare practices among students at the college.

Demographic questions

Please answer the following questions:

i. Age
ii. Gender
iii. Are you a student at Oman Health Sciences College?
iv. What year of study are you currently in?
v. What is your current program of study at Oman Health Sciences College?
vi. Have you received any education or training on lean management principles?
vii. How would you rate your familiarity with lean management concepts on a scale of 1 to 5?
viii. Have you participated in any projects or activities related to process improvement or efficiency within the college?
ix. Do you believe that lean management principles can be beneficial in healthcare settings?
x. Are you interested in learning more about lean management and its applications in healthcare?

Section 2: Knowledge, attitude and behaviour towards Lean management in healthcare settings

Knowledge related to Lean management in healthcare settings

The following items are designed to measure your level of Knowledge related to Lean management in healthcare settings. Please rate the following statements on a scale of 1 to 5, where 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral 4 = Agree 5 = Strongly Agree.

Variable	Item	1	2	3	4	5
Content	I have a good understanding of Lean management principles and their application in healthcare.					
	The training programs have effectively enhanced my knowledge of Lean methodologies in healthcare.					
	I feel confident in my ability to identify and eliminate waste in healthcare processes using Lean techniques.					
	The educational materials provided have helped me grasp the importance of continuous improvement in healthcare through Lean practices.					
	I believe I can effectively apply Lean thinking to optimise patient care and operational efficiency in healthcare settings					

Variable	Item	1	2	3	4	5
Training	The Lean management training programs adequately prepared me to understand Lean principles in healthcare.					
	I feel confident in my ability to apply Lean methodologies learned during training to improve healthcare processes.					
	The training sessions effectively enhanced my knowledge of Lean tools and techniques applicable in healthcare settings					
	I believe the training provided valuable insights into how Lean practices can optimise patient care delivery in healthcare.					
	The knowledge gained from Lean management training has equipped me to identify and address inefficiencies in healthcare operations					

Variable	Item	1	2	3	4	5
Assessment	I feel confident in my understanding of Lean management principles as they apply to healthcare settings.					
	The assessments conducted have effectively measured my knowledge of Lean tools and techniques in healthcare."					
	I believe the assessments have helped me identify areas for improvement in applying Lean practices in healthcare.					
	The feedback received on Lean management assessments has enhanced my understanding of process optimisation in healthcare.					
	I feel well-prepared to demonstrate my knowledge of Lean management concepts in real-world healthcare scenarios.					

Attitude related to Lean management in healthcare settings

The following items are designed to measure your attitude towards Lean management in healthcare settings. Please rate the following statements on a scale of 1 to 5, where: 1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

Variable	Item	1	2	3	4	5
Mindset	I believe that adopting Lean management practices can lead to improved efficiency and quality of care in healthcare settings.					
	I have a positive attitude towards learning and implementing Lean methodologies to enhance healthcare processes.					
	I am open to embracing change and innovation through the application of Lean principles in healthcare operations.					
	I perceive Lean management as a valuable tool for driving continuous improvement and patient-centred care in healthcare.					
	I am committed to developing a Lean mindset to optimise processes and enhance outcomes in healthcare delivery.					

Variable	Item	1	2	3	4	5
Culture	The organisational culture in healthcare settings values continuous improvement and efficiency through lean management practices.					
	There is a strong emphasis on teamwork and collaboration within the organisational culture to support lean initiatives in healthcare.					
	The culture in healthcare settings promotes a proactive approach to problem-solving and process improvement through lean methodologies.					
	Employees in healthcare organisations feel empowered to suggest and implement changes to enhance efficiency and quality within the lean framework.					
	The organisational culture fosters a learning environment where employees are encouraged to adapt to lean principles for continuous improvement in healthcare delivery.					

Variable	Item	1	2	3	4	5
Leadership	Leadership at healthcare organisations demonstrates a strong commitment to implementing lean management practices for continuous improvement.					
	I believe that effective leadership is essential for driving the successful adoption of lean principles in healthcare settings.					
	Leaders within healthcare organisations actively promote a culture of accountability and continuous learning through lean methodologies.					
	Leadership support and involvement are crucial for overcoming resistance and fostering a culture of change towards lean management in healthcare.					
	I agree that leadership plays a pivotal role in creating a supportive environment that encourages staff engagement and participation in lean initiatives within healthcare organisations.					

Behaviour related to Lean management in healthcare settings

The following items are designed to measure your behaviour towards Lean management in healthcare settings. Please rate the following statements on a scale of 1 to 5, where: 1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

Variable	Item	1	2	3	4	5
Application	I actively apply Lean management principles in my daily tasks to improve efficiency in healthcare settings.					
	I demonstrate a proactive approach to identifying and eliminating waste in healthcare processes using Lean methodologies					
	I collaborate effectively with team members to implement Lean strategies for continuous improvement in healthcare delivery.					
	I am committed to integrating Lean practices into my work to enhance patient care outcomes and operational effectiveness.					
	I actively seek opportunities to innovate and streamline processes using Lean principles to drive positive change in healthcare.					

Variable	Item	1	2	3	4	5
Feedback	I actively seek feedback on my application of Lean management principles in healthcare settings to enhance my performance.					
	I am open to receiving constructive feedback on my Lean management practices to drive continuous improvement in healthcare.					
	I effectively incorporate feedback from colleagues and supervisors to refine my Lean management skills in healthcare operations.					
	I value feedback as a tool for learning and development in applying Lean methodologies to healthcare processes.					
	I actively engage in feedback discussions to identify areas for growth and enhancement in Lean management practices in healthcare.					

Variable	Item	1	2	3	4	5
Role Modeling	I actively demonstrate Lean management principles through my actions and behaviours in healthcare settings.					
	I serve as a role model for my peers by consistently applying Lean methodologies to improve healthcare processes.					
	I lead by example in promoting a culture of continuous improvement through Lean practices in healthcare delivery.					
	I effectively communicate the importance of Lean management by modelling best practices in healthcare operations.					
	I inspire others to adopt Lean principles by demonstrating commitment and enthusiasm towards process optimisation in healthcare.					

Lean management in healthcare settings

The following items are designed to measure your perception towards Lean management in healthcare settings. Please rate the following statements on a scale of 1 to 5, where: 1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

Variable	Item	1	2	3	4	5
Lean management in healthcare settings	I believe that implementing lean management practices in healthcare settings can lead to improved patient outcomes and satisfaction.					
	I agree that lean methodologies can help healthcare organisations optimise processes and reduce waste, ultimately enhancing efficiency.					
	I believe that a culture of continuous improvement driven by lean principles is essential for enhancing the quality of healthcare services.					
	I agree that effective implementation of lean management can result in cost savings and resource optimisation within healthcare organisations.					
	I believe that embracing lean management principles can foster a culture of innovation and adaptability in healthcare settings.					

Appendix B:

The expected budget for implementing the study

Researchers Salaries **RA**	
Consultants	
Transportation	
Administration	
Dissemination- publications	
Miscellaneou	
Data analysis	
Total	

Appendix C:
Proposal timelines and Gantt chart

Year	2024			2025					
Month	**8-9**	**9-10**	**11-12**	**1-2**	**3-4**	**5-6**	**7-8**	**9-10**	**11-12**
Research Proposal Development									
Literature review									
Design Research Methodology									
Develop Data Collection Instrument									
Data Collection									
Data Analysis									
Report Writing									
Review and Revision									
Finalise research report									