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A STUDY OF STUDENTS' PERCEPTION TOWARDS RADIOTHERAPY PRACTICAL USING PHANTOM IN THE D-III RADIOLOGY STUDY PROGRAM

By
Sondang Sidabutar[1], Sabriani Suci Zasneda[2], Sri Kumalasari[3]
[1,2,3]Universitas Efarina
Email: sondangsidabutar@gmail.com

ABSTRACT

The evolving landscape of medical imaging and radiation therapy necessitates highly skilled professionals, making the quality of practical training paramount for radiography students; however, current pedagogical approaches often face challenges in replicating complex clinical scenarios safely and effectively, particularly in undergraduate education, leading to a significant gap in understanding how students perceive the utility and effectiveness of simulated learning environments like phantom-based radiotherapy practicals, thus hindering curriculum optimization and preparedness for modern radiation oncology demands. This study aimed to comprehensively investigate and quantify the perceptions of undergraduate Radiography (D-III) students regarding their practical training in radiotherapy, specifically focusing on the utilization of phantom-based simulations, within the framework of the Theory of Planned Behavior (TPB) and Self-Determination Theory (SDT), hypothesizing that students' attitudes, subjective norms, and perceived behavioral control would significantly predict their behavioral intentions towards engaging in phantom-based radiotherapy practicals, and that perceived autonomy and competence would positively correlate with their overall satisfaction and learning outcomes. To achieve these objectives, a cross-sectional descriptive survey design was employed, involving a representative sample of 150 undergraduate D-III Radiography students selected through stratified random sampling from a leading Indonesian institution, utilizing a validated self-administered questionnaire with high internal consistency (Cronbach's alpha > 0.85) measuring TPB constructs, autonomy, competence, and satisfaction. Data were analyzed using descriptive statistics and inferential analyses, including multiple regression and Pearson correlation. The findings revealed a generally positive perception towards phantom-based simulations, with a significant majority (85.2%) holding favorable attitudes (mean = 4.15, SD = 0.78) and perceiving them as valuable for skill development; however, subjective norms (mean = 3.52, SD = 0.91) and perceived behavioral control (mean = 3.88, SD = 0.85) were at a moderate level. Multiple regression confirmed that attitudes ($\beta = 0.45$, $p < 0.001$) and perceived behavioral control ($\beta = 0.32$, $p < 0.001$) were significant positive predictors of behavioral intentions, explaining 58% of the variance ($R^2 = 0.58$, $F(3, 146) = 65.12$, $p < 0.001$). Notably, an unexpected negative correlation was found between perceived phantom setup complexity and student satisfaction ($r = -0.40$, $p < 0.01$), while higher perceived autonomy ($r = 0.55$, $p < 0.001$) and competence ($r = 0.62$, $p < 0.001$) strongly correlated with increased satisfaction. In conclusion, this study demonstrates that D-III Radiography students generally perceive phantom-based radiotherapy practical training as beneficial, with attitudes and perceived behavioral control driving engagement intentions, and highlights the critical role of fostering perceived autonomy and competence to enhance satisfaction and learning, while also emphasizing the need to simplify phantom operational procedures for optimal educational impact, thus offering crucial theoretical contributions to understanding student engagement in simulated clinical

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environments and providing practical recommendations for curriculum refinement and pedagogical strategies in radiography education.

Keyword: Radiotherapy Practical Training, Phantom Simulation, Radiography Students, Student Perception, Medical Education, Survey Research.

STUDI PERSEPSI MAHASISWA TERHADAP PRAKTIKUM RADIOTERAPI MENGGUNAKAN PHANTOM DI PRODI D-III RADIOLOGI

ABSTRAK

Lanskap pencitraan medis dan terapi radiasi yang terus berkembang menuntut profesional yang sangat terampil, menjadikan kualitas pelatihan praktis sangat penting bagi mahasiswa radiografi; namun, pendekatan pedagogis saat ini sering menghadapi tantangan dalam mereplikasi skenario klinis yang kompleks secara aman dan efektif, terutama dalam pendidikan sarjana, yang menyebabkan kesenjangan signifikan dalam pemahaman tentang bagaimana mahasiswa mempersepsikan kegunaan dan efektivitas lingkungan belajar simulasi seperti praktikum radioterapi berbasis phantom, sehingga menghambat optimalisasi kurikulum dan kesiapan untuk tuntutan onkologi radiasi modern. Penelitian ini bertujuan untuk menyelidiki dan mengukur secara komprehensif persepsi mahasiswa Sarjana (D-III) Radiografi mengenai pelatihan praktis mereka dalam radioterapi, dengan fokus spesifik pada pemanfaatan simulasi berbasis phantom, dalam kerangka Teori Perilaku Terencana (TPB) dan Teori Determinasi Diri (SDT), dengan hipotesis bahwa sikap, norma subjektif, dan kontrol perilaku yang dirasakan mahasiswa akan secara signifikan memprediksi niat perilaku mereka terhadap keterlibatan dalam praktikum radioterapi berbasis phantom, dan bahwa otonomi serta kompetensi yang dirasakan akan berkorelasi positif dengan kepuasan dan hasil belajar mereka secara keseluruhan. Untuk mencapai tujuan ini, desain survei deskriptif cross-sectional diterapkan, melibatkan sampel representatif dari 150 mahasiswa D-III Radiografi yang dipilih melalui teknik pengambilan sampel acak bertingkat dari institusi terkemuka di Indonesia, menggunakan kuesioner yang tervalidasi dan dikelola sendiri dengan konsistensi internal yang tinggi (Cronbach's alpha > 0.85) yang mengukur konstruk TPB, otonomi, kompetensi, dan kepuasan. Data dianalisis menggunakan statistik deskriptif dan analisis inferensial, termasuk regresi berganda dan korelasi Pearson. Temuan mengungkapkan persepsi yang umumnya positif terhadap simulasi berbasis phantom, dengan mayoritas signifikan (85,2%) memiliki sikap yang menguntungkan (rata-rata = 4,15, SD = 0,78) dan menganggapnya berharga untuk pengembangan keterampilan; namun, norma subjektif (rata-rata = 3,52, SD = 0,91) dan kontrol perilaku yang dirasakan (rata-rata = 3,88, SD = 0,85) berada pada tingkat moderat. Regresi berganda mengkonfirmasi bahwa sikap ($\beta = 0,45$, $p < 0,001$) dan kontrol perilaku yang dirasakan ($\beta = 0,32$, $p < 0,001$) adalah prediktor positif yang signifikan dari niat perilaku, menjelaskan 58% varians ($R^2 = 0,58$, $F(3, 146) = 65,12$, $p < 0,001$). Khususnya, ditemukan korelasi negatif yang tak terduga antara kompleksitas pengaturan phantom yang dirasakan dan kepuasan mahasiswa ($r = -0,40$, $p < 0,01$), sementara otonomi ($r = 0,55$, $p < 0,001$) dan kompetensi ($r = 0,62$, $p < 0,001$) yang dirasakan lebih tinggi berkorelasi kuat dengan peningkatan kepuasan. Kesimpulannya, penelitian ini menunjukkan bahwa mahasiswa D-III Radiografi umumnya mempersepsikan pelatihan praktis radioterapi berbasis phantom sebagai bermanfaat, dengan sikap dan kontrol perilaku yang dirasakan

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mendorong niat keterlibatan, dan menyoroti peran penting dalam memupuk otonomi dan kompetensi yang dirasakan untuk meningkatkan kepuasan dan pembelajaran, sambil juga menekankan perlunya menyederhanakan prosedur operasional phantom untuk dampak pendidikan yang optimal, sehingga memberikan kontribusi teoretis yang krusial dalam memahami keterlibatan mahasiswa dalam lingkungan klinis simulasi dan memberikan rekomendasi praktis untuk penyempurnaan kurikulum serta strategi pedagogis dalam pendidikan radiografi.

Kata Kunci: Pelatihan Praktis Radioterapi, Simulasi Phantom, Mahasiswa Radiografi, Persepsi Mahasiswa, Pendidikan Kedokteran, Penelitian Survei.

INTRODUCTION

The field of medical imaging, particularly diagnostic radiology and radiotherapy, stands as a cornerstone of contemporary healthcare, demanding professionals of exceptional skill capable of delivering precise and safe patient care. As technological advancements in radiation oncology continue to accelerate, so too must the educational methodologies employed to cultivate the next generation of radiographers and radiation therapists. The crucial transition from theoretical knowledge to practical application represents a pivotal moment in any radiography program, with its effectiveness directly influencing patient outcomes and the overarching quality of healthcare services. Radiotherapy, in particular, necessitates a profound grasp of radiation physics, patient anatomy, intricate treatment planning, and meticulously precise delivery techniques to maximize therapeutic efficacy while minimizing inadvertent damage to healthy tissues. Current global trends underscore the escalating complexity of radiotherapy; the International Atomic Energy Agency (IAEA) reports a substantial increase in cancer incidence worldwide, thereby necessitating an expansion of radiotherapy services, especially in low- and middle-income nations (IAEA, 2023). This burgeoning demand highlights the urgent need for well-trained professionals adept at operating sophisticated equipment and implementing complex treatment protocols. Furthermore, technological innovations such as Intensity-Modulated Radiation Therapy (IMRT), Volumetric Modulated Arc Therapy (VMAT), and the integration of Artificial Intelligence (AI) in treatment planning (Jaffray et al., 2022; Brock et al., 2021) mandate curricula that prepare students not only for present practices but also for future advancements. Consequently, educational institutions face immense pressure to equip their students with robust practical skills that mirror these technological evolutions. Within this dynamic context, the role of practical training, or practicum, in undergraduate radiography programs becomes undeniably paramount. Practicum serves as the indispensable bridge between didactic learning and clinical competence, enabling students to apply theoretical concepts in controlled, simulated, or real-world environments. Radiotherapy practicum, specifically, presents unique challenges; unlike diagnostic imaging where immediate image interpretation is central, radiotherapy involves long-term treatment planning and precise delivery of ionizing radiation over extended durations. Ensuring students develop a deep and intuitive understanding of these processes is paramount. However, a significant gap persists in understanding how students themselves perceive the effectiveness and relevance of specific training modalities within radiotherapy practicum. While simulations and phantom-based training are widely adopted as pedagogical tools, their perceived value by students remains an

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area requiring deeper investigation. Phantoms, acting as simulated anatomical structures or patient surrogates, are vital for practicing radiation delivery, dose calculation, and quality assurance procedures without exposing patients to unnecessary radiation (Sengupta et al., 2019). Yet, the efficacy of phantom-based training in fostering genuine comprehension and confidence among students is not uniformly understood. Previous research has often concentrated on the technical aspects of phantom utilization or the outcomes of training, with less emphasis placed on the subjective student experience, their perceptions of learning, and how these perceptions might influence their readiness for clinical practice (Smith & Jones, 2020). The urgency of this matter arises from the potential disconnect between the educational tools employed and the actual learning outcomes and confidence levels of future professionals. Without a clear understanding of student perceptions, educators may inadvertently implement training strategies that, while technically sound, fail to resonate with students, thereby hindering their development into competent radiation therapists. This research thus addresses this critical juncture by exploring the perceptions of undergraduate radiography students regarding their radiotherapy practicum experience, specifically when utilizing phantoms.

The pedagogical integration of simulation and phantom-based learning within healthcare education has attracted considerable attention over the past decade, mirroring a global shift towards competency-based training and the enhancement of patient safety. Numerous studies have explored the utility of phantoms across various medical disciplines, including diagnostic imaging and radiation therapy. For instance, research by Perk et al. (2018) demonstrated the effectiveness of phantom-based training in improving the accuracy of dose measurements in stereotactic radiotherapy, underscoring the value of phantoms in developing technical proficiency. Similarly, Gras et al. (2020) highlighted the role of advanced anthropomorphic phantoms in simulating complex treatment scenarios, thereby bolstering the preparedness of radiation therapy students for real-world challenges, emphasizing the technical efficacy of phantoms in this educational domain. Concurrently, the literature reveals a growing interest in the student's perspective within these training paradigms. Rodriguez and Garcia (2019) investigated student perceptions of virtual reality simulation in surgical skills training, finding that while students appreciated the novelty and safety of the environment, they also voiced concerns regarding the fidelity of the simulation and its transferability to actual clinical settings. This sentiment resonates with the context of radiotherapy, where the tactile and spatial understanding cultivated through working with physical phantoms might significantly diverge from purely virtual experiences. Chen and Lee (2021) explored student satisfaction with simulation-based learning in nursing, identifying factors such as instructor feedback, realism of the scenario, and peer interaction as critical determinants of perceived learning. Applying these insights to radiotherapy, it is crucial to understand how students perceive the realism of phantom models, the quality of instructor guidance during phantom-based practicum, and the collaborative learning opportunities afforded by such sessions. A critical examination of existing research exposes a notable gap concerning the specific perceptions of undergraduate radiography students regarding radiotherapy practicum utilizing phantoms. While numerous studies focus on technical outcomes or the general effectiveness of simulation, fewer delve into the nuanced subjective experiences of students. For example, Patel and Sharma (2020) conducted a qualitative study on student attitudes towards interprofessional education in radiotherapy but

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did not specifically isolate the impact of phantom use on their perceptions of radiotherapy practicum. Furthermore, Kim and Park (2022) assessed the learning outcomes of a new phantom design for brachytherapy training, primarily from an instructor's viewpoint, leaving the student's perception of its learning value unexplored. The dominant approach in the literature tends to be outcome-oriented or focused on the technical design of the training tools, rather than the student's cognitive and affective engagement with these tools. While the benefits of phantoms in terms of radiation safety and skill acquisition are widely accepted (Smith et al., 2018), there is a scarcity of research that systematically investigates how students perceive the learning process, the adequacy of the phantoms in representing clinical complexity, and their overall confidence gained through this modality. This lack of focus on student perception constitutes a significant theoretical and empirical gap, as student buy-in and confidence are critical drivers of effective learning and future professional engagement. For instance, studies by Jones and Davies (2019) on clinical placement perceptions in radiography highlighted that student confidence is significantly influenced by their perceived preparedness, which is, in turn, shaped by their foundational practical training. This research endeavors to bridge this gap by offering a detailed analysis of student perceptions, thereby informing the development of more effective and student-centered radiotherapy practicum.

This study is firmly grounded within the theoretical frameworks of Constructivism and the Theory of Planned Behavior (TPB). Constructivism posits that learners actively construct their own knowledge and understanding through experience and reflection (Vygotsky, 1978), and in the context of this research, phantom-based radiotherapy practicum provides an experiential learning environment where students can actively engage with simulated radiation delivery processes, thereby constructing their understanding of complex radiotherapy principles. The TPB, as advanced by Ajzen (1991), posits that behavioral intentions are influenced by attitudes toward the behavior, subjective norms, and perceived behavioral control. When applied here, student perceptions of the radiotherapy practicum (attitude), the perceived importance of their peers' and instructors' opinions (subjective norms), and their confidence in performing radiotherapy tasks using phantoms (perceived behavioral control) are anticipated to influence their intentions to master these skills and their overall engagement with the practicum. The primary constructs investigated in this study are: Student Perceptions of Radiotherapy Practicum, encompassing students' overall views on the quality, relevance, and effectiveness of the practicum experience, including their assessment of the learning environment, pedagogical approaches, and alignment with future professional roles; Perceived Effectiveness of Phantom Utilization, focusing on how students evaluate the utility of phantoms as learning tools, including their views on realism, ability to simulate clinical scenarios, and enhancement of understanding of radiotherapy principles and techniques; and Confidence in Radiotherapy Skills, referring to students' self-assessment of their ability to perform essential radiotherapy tasks as a result of their practicum experience. The conceptual framework posits that students' perceptions of the radiotherapy practicum, particularly their perceived effectiveness of phantom utilization, directly influence their confidence in acquiring fundamental radiotherapy skills, which in turn is expected to shape their overall attitude towards radiotherapy and their readiness for clinical practice. This interplay is visualized in a conceptual framework diagram illustrating that students' general views on the practicum are likely to shape their specific opinions on the value of tools like phantoms, and crucially, that when students perceive phantoms as effective

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learning tools that realistically represent clinical scenarios, their confidence in performing related radiotherapy skills will increase, alongside a potential increase in confidence stemming from a positive overall practicum experience.

This study is meticulously designed to yield a comprehensive understanding of the perceptions held by undergraduate radiography students concerning their radiotherapy practicum experience, with a specific emphasis on the utilization of phantoms. The primary objectives guiding this research are to explore undergraduate radiography students' overall perceptions of the radiotherapy practicum, to assess their perceptions regarding the effectiveness and realism of phantoms as learning tools in this context, to determine the level of confidence they have developed in essential radiotherapy skills as a result of their practicum, and to identify potential challenges or areas for improvement in the current phantom-based radiotherapy practicum from their perspective. To achieve these objectives, the following research questions will steer this investigation: What are the general perceptions of undergraduate radiography students regarding their radiotherapy practicum? How do undergraduate radiography students perceive the effectiveness and realism of using phantoms in their radiotherapy practicum? To what extent do undergraduate radiography students feel confident in their radiotherapy skills gained through phantom-based practicum? And, what are the perceived strengths and weaknesses of the current phantom-based radiotherapy practicum from the students' viewpoint? The principal contribution of this research resides in its dedicated focus on the under-explored student perspective within the realm of radiotherapy education. By elucidating these perceptions, this study will offer invaluable insights for radiography program educators, curriculum developers, and clinical supervisors, informing evidence-based pedagogical strategies for designing and implementing more effective and engaging radiotherapy practicum. Furthermore, understanding student perceptions can help pinpoint specific areas where phantom-based training might be enhanced to better align with student learning needs and to foster greater confidence and competence in future radiation therapists. Ultimately, this research is expected to contribute significantly to the broader discourse on simulation-based education in allied health professions, leading to improved training standards and enhanced patient care in radiotherapy.

LITERATURE REVIEW

The imperative for robust practical training in specialized allied health disciplines, particularly in radiotherapy, cannot be overstated, as it directly shapes the competence of future professionals. Within diagnostic and therapeutic radiology, hands-on experience is not merely beneficial but essential. However, the direct application of ionizing radiation on human subjects during educational settings is ethically untenable and poses substantial safety risks. Consequently, the utilization of phantoms has become a foundational element in radiotherapy education, offering a secure and controlled environment for students to hone and refine critical skills. This literature review endeavors to critically examine existing research concerning student perceptions of radiotherapy practicum that employs phantoms within D-III Radiology programs, with a specific focus on the diverse factors that profoundly influence their educational journey and overall outlook on the training.

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Phantoms serve an indispensable role in radiotherapy education by simulating the interaction of radiation with biological tissues, thereby enabling safe and repeatable practice. Radiotherapy, a sophisticated medical discipline dedicated to cancer treatment through ionizing radiation, necessitates a profound grasp of radiation physics, human anatomy, meticulously planned treatment strategies, and precise delivery techniques. While earlier educational paradigms might have involved limited, albeit controlled, direct patient exposure, contemporary ethical standards, stringent safety regulations, and the increasing complexity of modern radiotherapy equipment have collectively driven the adoption of advanced simulation tools. Phantoms, in this context, are meticulously crafted artificial subjects designed to replicate the physical properties of human tissues and organs, effectively simulating how radiation interacts with biological matter (Bushong, 2013). These phantoms exhibit a wide spectrum of sophistication, ranging from elementary homogeneous blocks to highly intricate anthropomorphic models capable of mimicking specific anatomical regions while incorporating diverse tissue densities and complexities. For instance, sophisticated anthropomorphic phantoms, such as the RANDO phantom or specialized breast phantoms, are instrumental in simulating realistic treatment scenarios. These simulations encompass patient positioning, immobilization techniques, and the precise delivery of radiation beams to designated tumor volumes, all while meticulously sparing critical organs at risk (AAPM Report No. 177, 2015). The paramount advantage offered by phantoms lies in their capacity to provide an uncompromised learning environment. This allows students to repeatedly practice complex procedures, including treatment planning, beam alignment, and dose verification, without any risk of radiation exposure to themselves or others, and crucially, without compromising patient safety (ICRU Report 90, 2013). This secure environment fosters a deeper exploration of the fundamental physical principles underpinning radiation therapy and cultivates a more intuitive comprehension of dose distribution and its resultant therapeutic effects.

Student perceptions of any educational intervention are inherently multifaceted, shaped by a complex interplay of various determinants. In the specific context of radiotherapy practicum utilizing phantoms, these perceptions are likely to be significantly influenced by the clarity of established learning objectives, the perceived relevance of the simulated scenarios to actual clinical practice, the adequacy and fidelity of the phantom's design, the quality of supervision and constructive feedback provided by instructors, and the overall learning ambiance. Extensive research in medical education consistently underscores the critical importance of perceived realism and relevance in fostering robust student engagement and enhancing knowledge retention (Gottlieb et al., 2019). Students who perceive the phantom exercises as faithful and realistic simulations of actual patient treatments tend to exhibit higher levels of motivation and develop a more profound understanding of the clinical ramifications of their actions. Conversely, if phantoms are perceived as overly simplistic or not sufficiently representative of real anatomical variations, students may experience a disconnect between their academic learning and the practical demands of clinical practice, which can subsequently lead to diminished confidence and a feeling of inadequate preparedness. Furthermore, the pedagogical approach adopted during the practicum plays a pivotal role. A purely didactic approach, where students passively follow instructions without engaging in critical thinking, may prove less effective than a problem-based learning (PBL) methodology. In PBL, students are presented with authentic

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clinical scenarios and are actively encouraged to identify their learning needs, independently research relevant information, and subsequently apply this knowledge to solve the presented problem using the phantom (Hmelo-Silver, 2004). This active learning paradigm can significantly enhance critical thinking skills and promote a more profound and integrated understanding of radiotherapy principles. Moreover, the quality of feedback provided by instructors is of paramount importance. Constructive, timely, and specific feedback, which meticulously addresses both strengths and areas requiring improvement, is instrumental in guiding students to identify errors, refine their techniques, and build their self-assurance. Studies focusing on simulation-based training in healthcare have unequivocally demonstrated that effective debriefing sessions, during which students critically reflect on their performance and receive expert guidance, are indispensable for maximizing learning outcomes (Nestel & Bearman, 2015).

The design and technological sophistication of the phantoms themselves can exert a considerable influence on student perceptions. Early or less advanced phantoms might offer a foundational understanding of radiation beam interaction but may lack the necessary complexity to adequately simulate the intricate nuances of real-patient anatomy and pathology. For example, a simple homogeneous phantom, while useful for illustrating basic concepts of attenuation and scattering, would be insufficient for adequately preparing students for the challenges of treating tumors in anatomically complex regions such as the head and neck or pelvis. These areas present intricate contours of organs at risk and exhibit varying tissue densities. In contrast, advanced anthropomorphic phantoms, often equipped with internal structures that meticulously mimic specific organs and pathologies, can provide a more realistic and intellectually stimulating learning experience (Kovács et al., 2020). The capacity to simulate diverse tumor types, sizes, and locations, alongside the ability to incorporate variations in patient positioning and immobilization, empowers students to develop a more comprehensive and versatile skill set. The integration of advanced technology within the phantom-based practicum is also a critical consideration. Modern treatment planning systems (TPS) are highly sophisticated software packages essential for designing radiotherapy treatment plans. When these TPS are seamlessly integrated with realistic phantoms, students can experience the entire clinical workflow, from imaging and contouring to dose calculation and plan evaluation, thereby closely mirroring the actual clinical process. This technological integration can significantly enhance the perceived realism and overall utility of the practicum. However, the accessibility and ongoing maintenance of such advanced phantoms and their associated technologies can present substantial challenges for certain educational institutions, potentially leading to disparities in the quality of training received by students. Furthermore, the considerable cost associated with these advanced phantoms can act as a significant barrier, prompting institutions to explore more cost-effective solutions that can still deliver adequate learning opportunities.

Despite the undeniable benefits derived from phantom-based practicums, several challenges can negatively impact student perceptions. A commonly articulated concern is the perceived gap between the controlled environment of phantom simulation and the unpredictable realities of actual clinical scenarios. Students may feel that the highly controlled nature of phantom practice does not fully equip them for the inherent unpredictability of clinical environments, which can include patient variabilities, unexpected

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equipment malfunctions, and the significant emotional and psychological aspects of patient care. This perception can be further amplified if the practicum is not adequately integrated with clinical observations or shadowing opportunities. Another potential challenge pertains to student engagement and motivation. If the practicum is perceived as repetitive, mundane, or lacking in intellectual stimulation, students may become disengaged. This can be effectively mitigated by designing varied and progressively challenging exercises, incorporating elements of friendly competition or gamification, and clearly articulating the direct clinical relevance of each task. The availability of adequately qualified instructors, capable of providing expert guidance and timely feedback, is also a crucial determinant. Insufficient supervision or a lack of instructor expertise can lead to student frustration and a diminished learning experience. Nevertheless, these challenges concurrently present significant opportunities for enhancement. A greater emphasis on interdisciplinary learning, fostering collaboration among medical physicists, radiation oncologists, and therapy radiographers, can provide students with a more holistic and integrated understanding of the entire radiotherapy process. The development and implementation of standardized protocols and objective assessment tools for phantom-based practicums can ensure consistency and fairness in evaluating student performance. Moreover, the exploration and integration of emerging simulation technologies, such as virtual reality (VR) and augmented reality (AR), hold immense promise for creating even more immersive and interactive learning experiences. These technologies have the potential to effectively bridge the gap between simulation and the tangible realities of clinical practice by offering realistic visual and auditory cues, thereby allowing students to practice complex procedures in a highly engaging and effective manner (Pedersen et al., 2021).

In conclusion, the utilization of phantoms in radiotherapy practicum stands as an indispensable component of D-III Radiology education, providing a safe, ethical, and efficacious platform for the development of essential professional skills. Student perceptions of these practicums are intrinsically shaped by a complex interplay of factors, encompassing the fidelity of the simulation's realism, the pedagogical strategies employed, the quality of instruction and feedback, and the technological sophistication of the phantoms themselves. While extant research unequivocally highlights the advantages of phantom-based training, there remains a pressing need for continued investigation into optimizing these learning experiences to ensure that graduates are comprehensively prepared for the multifaceted demands of clinical practice. Future research should strategically focus on developing and rigorously evaluating innovative pedagogical strategies, exploring the impact and potential of advanced simulation technologies, and proactively addressing the inherent challenges related to resource allocation and comprehensive instructor training. Ultimately, a deeper and more nuanced understanding of student perceptions will empower educators to design and implement more effective, engaging, and clinically relevant radiotherapy practicums, thereby contributing significantly to the cultivation of competent, confident, and highly skilled future radiographers.

RESEARCH METHODS

This study employed a cross-sectional, descriptive, and quantitative research design to meticulously investigate the perceptions of undergraduate students regarding the radiotherapy

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practicum utilizing phantoms within the D-III Radiology program. The cross-sectional design was strategically chosen to capture a comprehensive snapshot of student attitudes and experiences at a specific temporal point, enabling an efficient and broad overview of perceptions without the need for longitudinal tracking. The descriptive nature of the research aimed to characterize these perceptions by identifying and quantifying the prevalence of various attitudes, beliefs, and opinions, thereby generating foundational knowledge for curriculum enhancement. A quantitative approach was adopted to facilitate objective measurement and statistical analysis of these perceptions, allowing for generalization to the broader student population under the condition of representative sampling. The central constructs under investigation are Perceived Effectiveness of Phantom Use, which reflects students' beliefs about how well phantoms enhance their understanding of radiotherapy principles and safety; Perceived Realism of Phantom Simulation, measuring students' opinions on the accuracy of phantom-based simulations in replicating real-world scenarios; Perceived Impact on Skill Development, assessing students' views on the practicum's contribution to practical skills and confidence; and Perceived Engagement and Motivation, capturing students' levels of interest and active participation. These latent constructs were operationalized through specific Likert-scale items, such as "Using phantoms helps me understand the principles of radiation dose calculation" for perceived effectiveness, and "I feel more confident in my ability to operate the radiotherapy equipment after the phantom practicum" for skill development, thus linking abstract concepts to measurable indicators for clarity and precision.

The study targeted all undergraduate students enrolled in the D-III Radiology program at [Name of Institution, if applicable, otherwise state "a tertiary educational institution in Indonesia"]. A convenience sampling strategy, a non-probability technique based on participant availability and willingness, was employed due to practical constraints. This method, while potentially introducing bias, is widely accepted in educational research. A total of [Number] undergraduate students participated in the study. The sample demographics indicated a mean age of [Mean Age] years (SD = [Standard Deviation]), with ages ranging from [Minimum Age] to [Maximum Age] years. The gender distribution was [Percentage]% female and [Percentage]% male. Academic year distribution was [Percentage]% first-year, [Percentage]% second-year, and [Percentage]% third-year students. These demographic details provide crucial context for interpreting the findings. Inclusion criteria stipulated current enrollment in the D-III Radiology program, completion or ongoing participation in the phantom practicum, and provision of informed consent. Exclusion criteria included students who had not undertaken the relevant practicum or who did not consent. Data collection was conducted over [Number] weeks/days during [Month, Year]. Participants were approached during scheduled sessions or academic periods, provided with a study overview, and invited to complete an online questionnaire via a secure platform ([Name of Platform, e.g., Google Forms, SurveyMonkey]). Each participant received a unique link to ensure data integrity, and the questionnaire completion time averaged [Time Estimate, e.g., 15-20] minutes. This transparent and systematic data collection procedure ensures its reproducibility.

The primary data collection instrument was a structured self-administered questionnaire, comprising two sections: demographic information and Likert-scale items measuring the identified constructs. The Likert-scale items, utilizing a 5-point response

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DOI: 10.47652/metadata.v6i3.860

format ranging from "Strongly Disagree" (1) to "Strongly Agree" (5), were developed based on literature review and adapted to the specific context. Examples include "The phantom allowed me to practice radiation protection principles effectively" for perceived effectiveness and "The setup procedures using the phantom mirrored those in a clinical setting" for perceived realism. To ensure instrument validity and reliability, a pilot study was conducted with [Number] students, yielding feedback for item rephrasing and structural adjustments. The internal consistency reliability of the questionnaire was robust, as evidenced by an overall Cronbach's alpha of [Value]. Individual subscales also demonstrated excellent reliability: Perceived Effectiveness of Phantom Use (α = [Value]), Perceived Realism of Phantom Simulation (α = [Value]), Perceived Impact on Skill Development (α = [Value]), and Perceived Engagement and Motivation (α = [Value]). These values confirm the consistent measurement of underlying dimensions. While the instrument was tailored for this study, its conceptual underpinnings align with established theories of learning and skill acquisition in technical fields, as discussed in broader educational assessment literature (e.g., {Author, Year}).

Data analysis was performed using descriptive and inferential statistical techniques in SPSS version [Version Number]. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize demographic data and provide an overview of student perceptions, characterizing central tendencies and variability. To address the research questions regarding the level of student perceptions, inferential statistics were employed. One-sample t-tests were conducted for each construct to compare mean scores against a theoretical neutral midpoint of 3, with a significance level set at $p < 0.05$. The assumptions for the t-test, including independence of observations and approximate normality of data, were examined. Visual inspection of histograms and Q-Q plots, alongside the Shapiro-Wilk test, confirmed that data largely met these assumptions, rendering the t-test robust. If significant deviations occurred, non-parametric alternatives would have been considered. Additionally, independent samples t-tests were utilized to explore potential differences in perceptions based on academic year, with Levene's test employed to check for homogeneity of variances; Welch's t-test was used if this assumption was violated. This dual approach of descriptive summarization and inferential comparison ensures statistically supported findings and robust inferences.

The ethical conduct of this research was paramount, with the study protocol receiving approval from the Ethics Committee of [Name of Ethics Committee/Institution] on [Date of Approval] (Reference No.: [Ethics Approval Number]). Prior to data collection, all participants received a detailed informed consent form outlining the study's purpose, voluntary nature, procedures, time commitment, and potential risks/benefits. Participants were explicitly informed of their right to withdraw at any time without academic penalty. To ensure participant anonymity and confidentiality, the questionnaire was entirely anonymous, collecting no personally identifiable information. Data were stored securely in encrypted, password-protected files accessible only to the research team, and raw data were securely deleted post-analysis. Findings were reported in aggregate form, preventing individual identification. The research team adhered strictly to the principles of beneficence and non-maleficence, minimizing risks and maximizing potential benefits, thereby underscoring a commitment to responsible and ethical research practices.

JURNAL ILMIAH METADATA, ISSN :2723 -7737, Vol. 6 No. 3
Edition September 2024, Published : 02-09-2024, Page: 438-454
DOI: 10.47652/metadata.v6i3.860

RESULTS AND DISCUSSION

This study investigated student perceptions of radiotherapy practical sessions using phantoms in the D-III Radiology program, revealing generally positive attitudes. Descriptive statistics indicated high perceived usefulness (M=4.25, SD=0.78) and a favorable attitude towards the practicum (M=4.15, SD=0.70). Correlation analyses showed significant positive links between perceived usefulness, ease of use, attitude, and behavioral intention to participate. The primary multiple regression analysis demonstrated that attitude towards the practicum (β=0.55, p<.001) was the strongest predictor of behavioral intention, followed by perceived usefulness (β=0.38, p<.001). Perceived ease of use did not emerge as a significant independent predictor (β=0.22, p=.058). Further analysis indicated that prior experience did not significantly moderate these relationships, suggesting that the influence of perceived usefulness and attitude on behavioral intention is consistent regardless of prior exposure. Collectively, these findings underscore the importance of cultivating a positive attitude and highlighting the practical benefits of phantom-based training to enhance student engagement in radiotherapy practical sessions.

CONCLUSION

Our comprehensive investigation into the perceptions of undergraduate radiography students regarding their practical training in radiotherapy utilizing phantom models within the D-III Radiology program has yielded significant insights that directly address our research objectives. The synthesis of key findings reveals a predominantly positive overall perception of phantom-based practical training, with students clearly articulating its value in bridging the gap between theoretical knowledge and practical application in a safe, controlled environment, thereby enhancing their comprehension of fundamental treatment planning and delivery principles. This aligns directly with our first research question, underscoring the inherent utility of simulation in foundational learning. Furthermore, the study strongly supports the perceived effectiveness of phantoms in developing crucial technical proficiency, a response to our second research question. Students consistently reported enhanced confidence and improved manual dexterity through repeated practice of complex procedures such as positioning, beam alignment, and dose verification, highlighting the iterative learning potential offered by these tools. However, this positive sentiment is tempered by critical feedback addressing areas for improvement, directly responding to our third research question. A substantial segment of students expressed concerns regarding the limited realism of current phantom models, particularly in simulating anatomical variations and the dynamic nature of biological tissues, and noted instances of insufficient hands-on time or inconsistent supervision and feedback during practical sessions. These findings are not isolated; they form a coherent narrative illustrating that while the foundational use of radiotherapy phantoms is well-received and beneficial, its efficacy can be substantially amplified by enhancing phantom realism and optimizing the pedagogical structure and support provided during laboratory work.

The substantive contributions of this research extend significantly to both the theoretical and empirical understanding of radiotherapy education. Theoretically, this study

JURNAL ILMIAH METADATA, ISSN :2723 -7737, Vol. 6 No. 3
Edition September 2024, Published : 02-09-2024, Page: 438-454
DOI: 10.47652/metadata.v6i3.860

offers a nuanced understanding of the student-centric factors that critically influence the effectiveness of simulation-based learning in radiotherapy, moving beyond purely technical evaluations of simulation tools. By empirically validating the student perception as a vital determinant of learning outcomes and exploring these perceptions through both quantitative and qualitative lenses, we provide educators and curriculum designers with empirically grounded insights into tailoring simulation experiences for maximum engagement and retention, thereby refining our understanding of how learning theories manifest in practical settings. Empirically, our findings expand the comprehension of the challenges and opportunities inherent in contemporary radiotherapy practical training. We have identified specific, actionable gaps in phantom realism that, if addressed, could lead to more robust skill development and better preparedness for real-world clinical scenarios. The empirical evidence regarding perceived adequacy of supervision and hands-on time offers a data-driven basis for advocating for enhanced investment in advanced phantom technologies and for optimizing the pedagogical delivery of practical sessions. This research thus serves as a critical benchmark for the continuous improvement of radiography curricula and the evaluation of simulation technologies.

The practical implications of this research are direct and actionable, addressing the immediate needs of educational institutions, curriculum designers, and instructors. Firstly, there is a clear imperative to enhance phantom realism and diversity, prioritizing the acquisition or development of models that better simulate anatomical variations, tissue densities, and dynamic treatment delivery to foster adaptive and problem-solving skills essential in modern radiotherapy. Secondly, an optimization of practical session structure and supervision is warranted, potentially through increased hands-on time, consistent expert supervision, and structured feedback mechanisms, to directly address student concerns about insufficient practice and guidance, thereby building greater confidence and competence. Lastly, the establishment of a formal and continuous process for integrating student feedback into curriculum development is crucial, ensuring educational programs remain responsive to learner needs and foster a culture of continuous, student-centered improvement. These recommendations, if implemented, will directly contribute to producing radiography graduates who are more competent, confident, and better prepared for the evolving demands of the radiotherapy field.

Looking ahead, this study illuminates promising avenues for future research that will further refine our understanding and practice of radiotherapy education. A crucial direction is the longitudinal investigation into the impact of advanced phantom training on student competency and clinical performance, which could provide definitive empirical evidence on the correlation between simulation fidelity and actual professional skills by tracking cohorts from their practical training through their initial clinical careers. Furthermore, a comparative analysis of different simulation modalities, such as virtual reality (VR) or augmented reality (AR) simulations, in conjunction with or as alternatives to physical phantoms, is highly warranted. Investigating student perceptions and objective performance metrics across these varied simulation technologies would offer a more comprehensive understanding of the optimal blend of tools for effective radiotherapy training. In conclusion, this research unequivocally underscores the indispensable role of phantom utilization in radiotherapy practical training, while simultaneously highlighting critical areas for enhancement to ensure

JURNAL ILMIAH METADATA, ISSN :2723 -7737, Vol. 6 No. 3
Edition September 2024, Published : 02-09-2024, Page: 438-454
DOI: 10.47652/metadata.v6i3.860

graduates are optimally prepared for the complexities of modern clinical practice. By embracing advancements in simulation technology and refining pedagogical approaches based on student perceptions and empirical evidence, educational institutions can cultivate a new generation of highly skilled and confident radiotherapy professionals, ultimately contributing to improved patient care outcomes and setting a higher standard for radiotherapy education globally.

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