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Short Communication

Enhancing Undergraduate Radiography Education Through Quantitative Imaging Research Projects

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Abstract

Applied research and evidence-based practice (EBP) has become part of the core competencies required for the continuous growth of the radiography profession. This is coupled with noticeable changes in the radiography curriculum with increased need to conduct research as part of their undergraduate studies. Further, in some countries, professional regulatory bodies stipulate research participation as one of the competencies for practitioners. Successful implementation of applied research and EBP requires suitable approaches to enhance undergraduate radiography education.
In this discussion paper, the authors uphold quantitative imaging research as an approach that can be utilized to enhance undergraduate radiography education while contributing to research in the profession. An overview of the skills needed in radiography and how these are associated with research is presented. Further, the pedagogical basis of research with a specific focus on discovery learning is briefly discussed, followed by highlighting quantitative imaging research as a teaching tool that contributes to quantitative reasoning and cognition.
The paper concludes that quantitative imaging research could contribute significantly to enhancing undergraduate radiography education and contribute to research growth in the profession.

Keywords: cognition; clinical reasoning; reflective practice; artificial intelligence;knowledge; quantitative imaging; feedback

Introduction

Healthcare research remains one of the critical elements for enhancing the delivery of care that is beneficial to patients, and communities, and creates public value for services.[1,2] Neep[3] asserts that research keeps the radiography profession moving forward while providing a high-quality, safe, and efficient service to patients. In order to enhance research in radiography and realize its benefits, there is a need to build a research culture in undergraduate training. Research culture in this context refers to establishing the research communities' norms, values, behaviors, expectations, and attitudes which ultimately impact collaborations, career paths, and recognition of the importance of research.[4]

Recently there has been significant growth in radiography qualifications offered at the honors level, requiring students to engage in research before they graduate. The change in the higher education landscape generally necessitates this growth. In some countries, regulatory bodies legislate these requirements for research participation and/or competence. For example, in the United Kingdom, the Society of Radiographers, in its research strategy, prioritized that research must be embedded at all levels of radiography practice and education, emphasizing the need to embed research skills in the learning experience of every radiography student.[5,6] In New Zealand, the Medical Radiation Technologists Board (MRTB)[7] upholds both applied research and evidence-based practice (EBP) as key behaviors to contribute to the competencies of quality management, making effective decisions, facilitation of education of colleagues, application and evaluation of radiography clinical practice, and competencies related to the actual professional practice. Similarly, the Australian Medical Radiation Practice Board (MRPB),[8] in its legislated Professional *Capabilities for Medical Radiation Practitioners*, upholds the need for radiographers to engage in evidence-informed practice and reflective practice.

The changes in the curriculum outcomes are happening parallel to the increasing professional demands for practitioners to contribute to the profession's growth through research. For example, Malamateniou[9] asserts that radiography is dynamic, largely due to technological developments. As such, the latest developments like artificial intelligence (AI) are increasingly being embedded into aspects of radiology workflow management, image acquisition, therapy planning, data reconstruction, post-processing, image quality, and improving diagnosis and treatment.[9]

These developments prompt the need to consider multiple approaches to be used in teaching radiography practice while increasing research participation. One of these approaches is quantitative imaging research. This paper aims to highlight how quantitative imaging research can be utilized to enhance undergraduate radiography education.

Skills Needed in Radiography

In addition to the critical thinking and reflective practice that have been highlighted as fundamental skills required to practice radiography, there are several other skills that radiographers require. The key skill among these is quantitative imaging which is becoming an increasingly common tool in current radiography and radiology practice. Quantitative imaging has been defined as the extraction of quantifiable features from medical images as part of the diagnostic process and includes the development, standardization, and optimization of anatomical, pathological, functional, and molecular imaging acquisition protocols, data analysis, display methods, and reporting structures.[10,11]

The clinical utility of quantitative imaging covers various aspects of radiology and radiography, including tools for performing quantitative imaging, clinical applications of quantitative imaging, reporting of quantitative imaging studies, and how to deal with challenges related to quantitative imaging in clinical practice.[10,12] Therefore, clinical applications of quantitative imaging include measuring tissue dimensions, tissue characterization, and vascular flow which are performed using different modalities i.e. Computerised Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasound (US), Nuclear Medicine (NM), and dual-energy X-ray absorptiometry (DXA). The applications of quantitative imaging are closely aligned with radiography practice and research. Therefore, radiography practice education can be enhanced through QUANTITATIVE IMAGING research.

Törnroos et al.[13] highlight several research priorities in radiography, which include the benefits of using AI, the safe integration of AI into practice, the impact of new technology, evidence-based clinical practices, radiation safety, radiation optimization, patient outcomes in radiography, and image interpretation. These research priorities align well with quantitative imaging research approaches and therefore require radiographers to be involved in EBP while being multi-skilled or adaptable to role changes and practice.[5,9]

Evidence-based practice has been touted to offer the integration of the best research evidence with clinical knowledge, expertise, and patient values.[14] Brettle[15] defines EBP, in the radiography context, as the combination of clinical expertise and the best available research-based evidence, patient preferences, and available resources to inform radiography practice. For radiographers to increase their EBP, a 5-stage process (also called the 5 A's) may be used: 1) ask; 2) acquire; 3) appraise; 4) apply; and 5) assess.[3,15] Quantitative imaging research, therefore, could be useful in enhancing EBP when used as a teaching and research tool.

The Pedagogical Basis of Research

Research has been proven to develop various skills in students. Students involved in research develop critical thinking expertise, analytical, research, clinical reasoning, and communication skills that prepare them for the globalized society and practice.[16] Further, Stojsavljevic[17] and Arnold[18] highlight that research allows students to work with faculty experts which helps them develop a deeper understanding of their discipline, increases their passion for the discipline, develop greater confidence and independence, helps students identify themselves as scholars who have an impact on their communities, gain a better understanding of career and education path, and hone their leadership skills.

The development of these skills in students aligns with constructivism which is a theory based on observation and scientific study of how people learn. It states that people construct their own meaning and knowledge of the world, through experiencing things and reflecting on those experiences i.e. students learn by doing.[19-21] In the context of this paper, constructivism is presented with reference to the learning paradigm rather than the research paradigm. Therefore, involvement in research related to the student's discipline and practice, i.e., quantitative imaging research, is an excellent platform for the students to learn by doing.

Attwell and Hughes[22] highlight that the student's role in knowledge acquisition is through puzzlement, experience, reflection, and construction based on eight principles that provide the essence of constructivism. These principles include that learning should take place in authentic and real-world environments, and learning should involve social negotiation and mediation. Constructivism also supports scaffolding learning, which uses various instructional techniques to move students progressively toward stronger understanding and, ultimately, greater independence in the learning process.[20] Scaffolding, therefore, allows students to internalize the knowledge, leading to enhanced mastery. In the context of quantitative imaging research, students will use scaffolding to research and organize information as they compile their research report/dissertation/thesis with a clear research question, problem statement, literature review, methodology, analysis, results, conclusion, and references.

One of the teaching methods in constructivism is discovery learning (or learning by exploration) which can be thought to corroborate quantitative imaging research. In discovery learning, students are provided with a problem to solve and are left to figure it out for themselves by drawing on their past experiences, discussing possible solutions, and exploring their surroundings to find a solution together.[21,23] It encourages engagement and learning new things based on the students' interests. The two types of discovery learning that have a better fit with quantitative imaging research are:[23]

- Expositional discovery learning has maximal help from the teacher and involves hands-on activities such as conducting an experiment to test a hypothesis or building a model to test an idea.
- Guided discovery learning (directed discovery) has minimal help from the teacher in the form of clues and information, but the learner makes their own discoveries by solving problems, completing tasks, and making meaningful associations. It focuses on the process of problem-solving while the teacher acts in a supportive role.

In the context of quantitative imaging research, whether expositional discovery learning or guided discovery learning is utilized will depend on the project's complexity level. The more complex projects will require maximum supervisor support and therefore, the learner will be learning using expositional discovery learning while projects that require minimal supervisor support will be utilizing guided discovery learning.
The benefits of discovery learning include increased student engagement, promoting autonomy and independence, motivating students to learn, increasing levels of retention, and generating lifelong results.[23] These benefits are similar to those of constructivism which include that:[21]

- Social and communication skills are enhanced when using constructivism. The focus on thinking and understanding rather than rote memorization leads to better retention.
- Students learn more when they are engaged and active in the learning process.
- The skills that the students learn can be used in the real world since constructivist learning is a transferable skill.
- Students have a sense of ownership over their learning.

Quantitative Imaging Research as a Teaching Tool

The training of radiographers involves acquiring new knowledge which informs reasoning. The latter is associated with thinking, cognition, and intellect, and may be subdivided into deductive reasoning, inductive reasoning, and abductive reasoning; non-classical logical reasoning: analogical reasoning, commonsense reasoning, defeasible reasoning, probabilistic reasoning; and other modes of reasoning such as counterfactual reasoning, intuitive reasoning, and verbal reasoning.[24] In addition, Study.com[25] highlights that reasoning is also quantitative (quantitative reasoning) and therefore requires quantitative skills, which include reading and identifying mathematical information, interpreting and analyzing mathematical information, finding appropriate methods of solving problems, evaluating the validity of results, and effective communication of quantitative concepts.

Cognition is defined as the mental action of acquiring knowledge and understanding through thought, experience, and the senses.[24] Cognitive skills include aspects like memory, logic and reasoning, attention span, and auditory and visual ability, and the development of these cognitive skills depends on quantitative skills.[25] Therefore, the training of radiographers should include cognitive and quantitative reasoning approaches.

Quantitative imaging Research Paradigm in Radiography

Radiography is a discipline requiring constant research due to the dynamics that exist in the profession as alluded to earlier. Radiographers operate in the natural science (physics, e.g., machines) and social science (psychology, e.g., patients) domains, and these domains thrive on the application of quantitative knowledge in practice.[26] This necessitates that radiographers need to be equipped to improve everyday practice by solving practical problems through quantitative approaches. Further, quantitative imaging research has several advantages: it can be tested and checked, has straightforward analysis, and carries some prestige.[27] Woodbury and Kuhnke[28] assert that EBP relies on Quantitative Imaging research studies that provide the highest levels of evidence for decisions on practice. Quantitative radiography research projects often require medical image analysis tools for performing image segmentation, registration, statistical analysis, etc. With the rapid development of open source and freely-available scientific research software tools, such convenient and easy-to-use tools can be easily obtained and applied in quantitative radiography research projects.

However, it must be appreciated that radiography research projects can take on positivism (quantitative research), interpretivism (qualitative research), or both paradigms. The latter is generally applicable in mixed methods studies or those that use the design science research approach. When considering these paradigms, they each have their own strengths and weaknesses in using research as a teaching tool. The philosophical assumptions of the positivist paradigm have ontology, epistemology, methodology, and axiology that could enhance undergraduate radiography education (Table 1).

Table 1: Philosophical assumptions of three research perspectives.[29]

Basic Belief	Research Perspective		
	Positivist	**Interpretive**	**Design**
Ontology	A single reality; knowable, probabilistic.	Multiple realities, socially constructed.	Multiple, contextually situated alternative world-states. Socio-technologically enabled.
Epistemology	Objective: dispassionate. Detached observer of truth.	Subjective, i.e. values and knowledge emerge from the researcher-participant interaction.	Knowing through making: objectively constrained construction within a context. Iterative circumscription.
Methodology	Observation; quantitative, statistical.	Participation; qualitative. Hermeneutical, dialectical.	Developmental. Measure artificial impacts on the composite system.
Axiology	Truth: universal and beautiful; prediction.	Understanding: situated and description.	Control; creation; progress (i.e. improvement); understanding.

The positivist approach allows the researchers to collect data from large samples and collate it into data sets, tracing patterns; trends; and correlations, finding cause and effect relationships and making predictions through statistical analysis.[30] This approach fits in well with the undergraduate radiography education needs.

Discussion

Radiography is developing rapidly, including imaging equipment or intelligent radiography analytics. Our radiography undergraduate education also needs to keep pace with the times, improve students' abilities, and increase their future adaptability and competitiveness.

Artificial intelligence is developing rapidly in radiography. It is the future trend and has many applications in the profession.[9,31-33] Quantitative imaging is the basis of intelligent medical image analysis.[10,11] The intelligent medical image analysis project needs to be strengthened in undergraduate radiography teaching.

Quantitative medical image analysis projects are easy to implement with lots of tools, and lots of data. This type of project design has a certain degree of flexibility and can be matched to the student's ability and/or knowledge while allowing learning to take place in an authentic and real-world environment.[22] Further, the difficulty of project analysis can have different levels and could be an ideal platform for scaffolding learning thus increasing mastery.[20] These levels of project analysis can be reflected in the size of the data volume, the number of imaging modalities, the level of statistical analysis, rationality and interpretation of analysis results, etc. The different levels of difficulty will also determine the level of supervision that is required for each student, leading to either expositional or guided discovery learning being used for each student.[23]

Quantitative research, in the form of quantitative imaging research, could improve the knowledge, abilities, and skills of radiography students including the following: literature review, finding knowledge gaps, learning to use quantitative imaging analysis tools, improving data analytics or AI skills, keeping up with the trend of technological development, and improving problem-solving and lifelong learning skills.[24,25,30] Further, the skills developed through quantitative imaging research are those aligned with constructivism and discovery learning as narrated earlier.[21,23]

Conclusion

Applied research and EBP in undergraduate radiography education and practice continue to grow, necessitating suitable approaches to incorporate research as a teaching tool at the undergraduate level. The skills required for radiography practice could be enhanced with the use of suitable research approaches being incorporated into undergraduate radiography education. The pedagogical basis of quantitative research supports its incorporation as a teaching tool in radiography undergraduate education to contribute to research growth in the profession and enhance critical thinking, reflective practice, and clinical reasoning.

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