Chapter 4
The Impacts of Integrating Picture Archiving and Communication System (PACS) in Medical Education on Trainees

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Abstract With advancements in technology, Picture Archiving and Communication System (PACS) in Radiology and Radiography has played an essential role in archiving and retrieving medical images. Other functions of PACS also include visualising and manipulating patient's images for an accurate diagnosis. Without the basic knowledge of PACS, users would face technical challenges leading to a delay in medical care delivery. Starting PACS training with healthcare students would help to acquaint them with the system and serve as a tool to supplement their learning. Hence, the aim of this systematic review is to evaluate the impact of implementing PACS training on trainees. Previous studies were included based on the keywords generated for the search strategy. Our exclusion criteria consisted of articles published before 2000, those not related to PACS, and conference abstracts. Scientific databases such as PubMed, Cinahl, Cochrane, Web of Science, Embase, Medline (Ovid) were used. After reviewing the studies based on these criteria, 21 studies were included in this review and six themes were generated. These themes included 'Self-efficacy', 'Skills of Inquiry', 'Interest and Motivation', 'Application to clinical practice', 'Content and Process knowledge' and 'Utility of PACS'. The results reported an increase in trainees' self-confidence when using PACS. Trainees felt more ready for their future practice and clinicals. Studies showed that trainees were able to develop critical thinking skills and helped to increase their interest and

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motivation in radiology. Trainees learnt new clinical and imaging knowledge from PACS training and found it useful for studying radiology, understanding anatomy, and learning indications for imaging studies. The PACS training also provided trainees the perspective of a practitioner and the image manipulation tools in PACS aided them in visualising anatomy and understanding difficult materials effectively. Hence, the consensus reached based on the results is that implementing PACS training has a positive impact on trainees.

Keywords Technology · Self-efficacy · Skills of inquiry · Interest and motivation · e-learning · Medical imaging · Picture Archiving and Communication System (PACS)

4.1 Introduction

Diagnostic imaging is a key component of information that affects the care that a patient receives (Hood & Scott, 2006). For the longest time, hard films were used for imaging. However, one of the major problems with films was that they were often lost and may not ever be interpreted. Approximately 10–20% of hard copy films are missing or unavailable when needed, possibly resulting in incorrect management as the images were often used to assess disease remission or progression (Kinnunen & Pohjonen, 2001). The loss of images would also result in the patient undergoing repeated examination, causing unnecessary re-exposure to x-rays, delays in the final diagnosis and additional overall health costs (Arenson et al., 2000).

With the advancements in technology and filmless radiography becoming more prevalent, it has allowed for the implementation of picture archiving and communication system (PACS) within hospitals (Bansal, 2006). PACS is a system that allows archiving, transmitting, distributing, and displaying diagnostic images. It consists of various imaging modalities such as CT, MR, ultrasound as well as archiving and display workstations that are connected via various digital networks (Law & Zhou, 2003). PACS has been increasingly incorporated within the hospital framework as it makes images available and accessible on multiple workstations simultaneously, aiding in clinical decision making and providing efficient patient care (Alhajeri et al., 2017) as illustrated in Fig. 4.1. In a study by Hussein et al., (2009) it was demonstrated that PACS makes it easier to get connected with other healthcare centres and therefore increasing the use and expansion of this technology.

It is essential that hospitals place a strong emphasis on conducting indispensable workshops for the healthcare professionals (HCP) to improve themselves with adequate knowledge, optimising quality care and services for the patients, especially with the introduction of new technology. In a study by Dubey et al., (2010) one of the factors found to be essential for a successful implementation of PACS was conducting proper training for PACS users. About 30 years ago, refresher courses on PACS were offered during annual scientific meetings attended by radiologists and physicians. Various manufacturers conducted workshops that were focused on retrieving images

Fig. 4.1 Picture archiving and communication system (PACS) functionality diagram

and displaying them on the workstations as well as using the tools to enhance image interpretation (Protopapas et al., 1996). In the 1990s, instead of didactic refresher courses, hands-on workshops were offered on how to use the viewing workstations, and more recently PACS training have been conducted at the clinical sites.

As important as it is to train HCP, it is also crucial to expose PACS to healthcare students who will be the future HCPs attending to patients. Giving PACS training can help students familiarise with the system before embarking on their clinical attachments. PACS can also be utilised as a learning tool whereby students are able to use the images to supplement their learning. However, the issue with this was that scheduling the training sessions during working hours was not easy as either the radiologists or physicians were busy using the workstations (Protopapas et al., 1996). Therefore, the teaching model initially comprised of didactic lectures via PowerPoint and access to static radiology imaging was mostly found in textbooks. Basic image manipulation such as window width and level as well as reconstruction was only taught by theory. With the advancements in technology, in the year 2000, the Hong Kong Polytechnic University (PolyU) utilised the PACS simulator as a training tool for its undergraduate and postgraduate programmes. The PACS simulator provided a setting for a more basic understanding of PACS and offered a practical experience for the trainees in a more controlled environment (Law & Zhou, 2003). With this, several institutions worldwide started experimenting with the implementation of a more integrated teaching method, allowing trainees to have hands-on practice using PACS. Therefore, the objective of this systematic review is to evaluate the impact of implementing PACS training on trainees.

4.2 Methods

4.2.1 Search Strategy

Scientific literature databases like PubMed, Cinahl, Cochrane, Web of Science, Embase, Medline (Ovid) were searched for relevant published studies using a search protocol that consisted of various forms of the terms "PACS", "Curriculum", "Students" and "Impact". The full search strategy is shown in Table 4.1.

4.2.2 Eligibility Criteria

To be included in this systematic review, studies had to be published after the year 2000. Considering the fact that the teaching syllabus for radiology has evolved significantly, we wanted to assess studies that were more relevant to the current syllabus being used to teach trainees of this generation. Studies were also only included if they were written in English in order for the reviewers to fully understand the contents of the study. While it is possible to translate the articles to English, some of the contents may get lost in translation. We did not include conference abstracts as they did not provide enough information on the methods used and the extent of PACS involvement.

4.2.3 Study Selection and Data Extraction

After removing duplicate studies, reviewers examined the title and abstract and applied the eligibility criteria to select the studies for inclusion. A minimum of two reviewers collectively checked and screened the records for inclusion. If both reviewers were unable to come to a conclusion, the two reviewers stated their opinions and discussed until a consensus was reached. However, when an agreement could not be made, the third reviewer stepped in and made an unbiased judgement after considering the opinions from both sides. Abstracts that mentioned PACS or simulated PACS were included for full-text article assessment. Software such as Zotero and Microsoft Excel spreadsheets were used for recording studies and articles. Rayyan was used as a platform for reviewers to screen the records without bias as the decisions of each reviewer were not visible to others until all the articles had been screened. The data from the selected articles were independently extracted onto a data extraction sheet and counter checked by another reviewer. The data extracted included author, year of publication, study design, methods and measurements, country of origin, total number of students, student demographics and intervention used.

Table 4.1 Search strategy

Database	Search terms
PubMed	(((“Radiology information systems”[mesh] OR “radiology/education”[MAJR] OR “picture archive and communication system” OR “pacs” OR “image teaching” OR “radiology information system”) AND (“Curriculum”[mesh] OR “curriculum/trends”[MAJR] OR education OR module OR learning OR program OR training OR course)) AND (“Education, medical, undergraduate/trends”[MAJR] OR undergraduate* OR student OR medical OR nursing OR “allied health”)) AND (evaluate OR effectiveness OR effect* OR cause OR result*)
CINAHL	(“picture archive and communication system” OR pacs OR “image teaching” OR “radiology information system”) AND (education OR module OR learning OR program OR training OR course) and (undergraduate OR student OR medical OR nursing OR “allied health”) AND (evaluate OR effectiveness OR effect OR cause OR result)
Cochrane	“picture archive and communication system” OR pacs OR “image teaching” OR “radiology information system” AND education OR module OR learning OR program OR training OR course AND undergraduate OR student OR medical OR nursing OR “allied health” AND evaluate OR effectiveness OR effect OR cause OR result
Web of science	(((TS = (“picture archive and communication system” OR pacs OR “image teaching” OR “radiology information system”)) AND TS = (education OR module OR learning OR program OR training OR course)) AND TS = (undergraduate OR student OR medical OR nursing OR “allied health”)) AND TS = (evaluate OR effectiveness OR effect OR cause OR result)
Embase	(‘picture archive and communication system’ OR pacs OR ‘image teaching’ OR ‘radiology information system’) AND (education OR module OR learning OR program OR training OR course) AND (undergraduate OR student OR medical OR nursing OR ‘allied health’) AND (evaluate OR effectiveness OR effect OR cause OR result)

(continued)

Table 4.1 (continued)

Database	Search terms
Medline (Ovid)	(((picture archive and communication system) OR pacs OR image teaching OR radiology information system) AND (education OR module OR learning OR program OR training OR course) AND (undergraduate OR student OR medical OR nursing OR allied health) AND (evaluate OR effectiveness OR effect OR cause OR result))

Note Databases and search terms used to identify literature

4.3 Results

4.3.1 Search Strategy and Article Selection

The details of the search strategy and articles selected are shown in Fig. 4.2. During the initial search strategy, a total of 4069 articles were found. After removing duplicate articles, 3535 articles remained. The titles and abstracts of the articles were reviewed according to the inclusion criteria, and 3488 articles were excluded. The full texts of the remaining 47 articles were studied in detail. Subsequently, 26 articles were excluded from the review resulting in 21 articles to be included in this review.

4.3.2 Study Design

Most of the studies were conducted in the USA (n = 14), followed by two studies from China and Germany each and one study from Canada, Hong Kong, and India each. The study design utilised by majority of the studies were cross-sectional studies (n = 9). The three reviewers independently assessed the included studies and discussed their initial thoughts on broad descriptive coding themes. The codes that were accepted by all were then noted in an excel sheet. These were then used by the reviewers to conduct coding of the remaining included studies. The reviewers met regularly to discuss coding as it developed. After analysis of all the studies, groups of related codes were identified and grouped together to form a theme. The summary of each theme was written, discussed, and refined. This process involved repeated reference to the respective papers to ensure that there is consistency with the study findings. The 6 themes generated after analysis of the 21 included studies are Self-efficacy, Skills of Inquiry, Interest and Motivation, Application to clinical practice, Content and Process knowledge and Utility of PACS (Table 4.2).

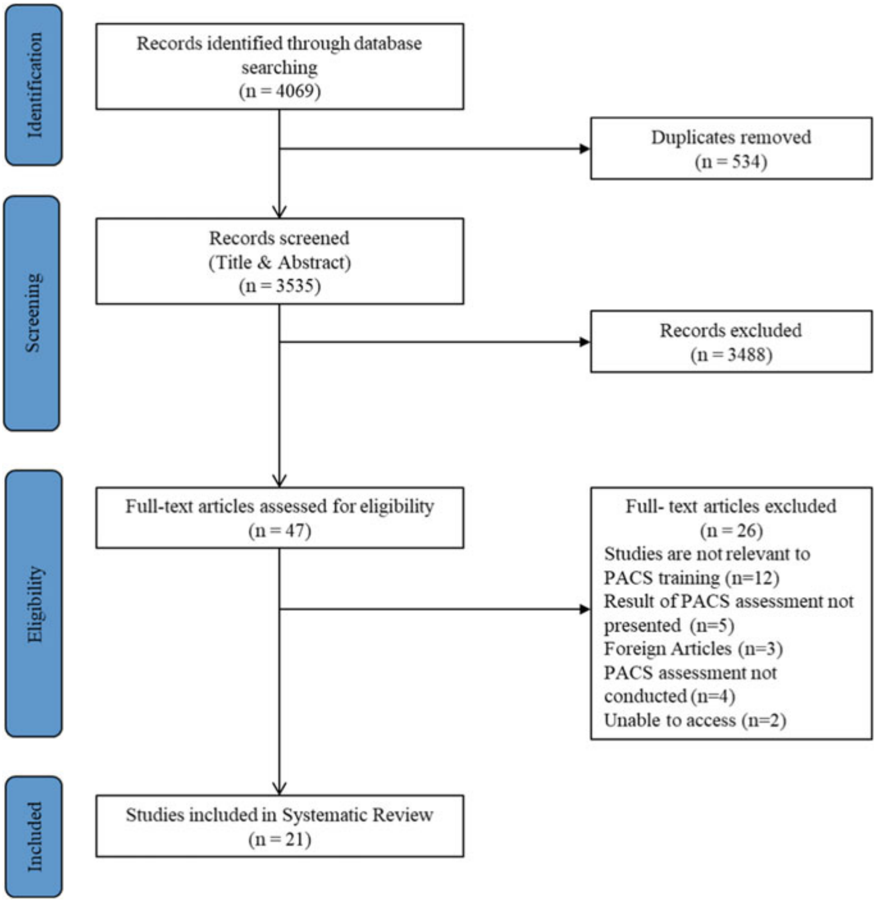

Fig. 4.2 PRISMA flowchart

4.3.2.1 Self-efficacy

In a randomised control study conducted by Chen et al. (2019) the experimental group were exposed to whole cases using PACS, where they were free to utilise the basic reconstruction capability and explore the image characteristics on their own. This allowed the students to have an increased familiarity with Digital Imaging and Communications in Medicine (DICOM) viewer and anatomy, strengthening their self-confidence. Huang et al. (2021) conducted a post-course survey with 34 students using a scale of zero to hundred (0 = strongly disagree, 50 = neutral, 100 = strongly agree). The students responded with an average rating of 89.5 (range 63–100) regarding their confidence in reviewing and interpreting future studies in comparison to review with teaching which was the current standard.

Table 4.2 Summary of thematic analysis

Theme	Description
Self-efficacy	The range of self-confidence the trainee has in his/her ability to use PACS
Skills of inquiry	Trainees are able to attain procedural skills such as critical thinking and problem-solving skills, including asking questions, collecting, diagnosing, analysing, and interpreting clinical data and images
Interest and motivation	PACS serves as a self-directed learning material, garnering a learning interest in radiology. Trainees are motivated to learn using PACS software and recommend it to their peers
Application to clinical practice	Trainees are able to apply knowledge obtained from simulation to clinical practice, better understanding and seamless transition of their role and the use of PACS in the clinical setting
Radiological science and technology	Trainees learn new knowledge on imaging or PACS processes. Improve their understanding and recollection of anatomy, radiology, and clinical content
Utility of PACS	PACS' functions which make it a superior tool in improving trainees' workflow efficiently and providing an effective learning platform in enhancing trainees learning experiences and education

This was also similarly reported by a study conducted by Rengier et al. (2009) where there was an improvement in the students' confidence in their ability to interpret radiological cross sections. In a free-response survey conducted by Novelline et al. (2001) students mentioned that ***"… I feel confident that I can do this for my future presentations."***

Two studies by Restauri et al., (2017, 2018) evaluated the implementation of teaching PACS application into the educational programme of undergraduate medical education. The free response recorded from students stated that they ***"feel more confident about radiology/imaging"*** as well as ***"interpret radiology images so much better"*** and they feel more confident reading and thinking about US and CT. In the second study conducted in 2018, the medical students reported statistically significant improvements in confidence levels with respect to interpretive and noninterpretive skills after using the TPACS. Increased levels of confidence in imaging were also observed as they were able to utilise the PACS workstation. This was also supported by a study conducted by Smith and Boscak (2021), in which confidence in study ordering and image interpretation increased subsequently after the restructured emergency radiology course. Through this course, students were able to review unknown imaging cases via a browser based Pacsbin platform. Towbin et al. (2007) also reported that the study group that used the PACS simulator tended to feel more ready and less nervous. However, this result was not statistically significant, possibly attributed to the small sample size.

4.3.2.2 Skills of Inquiry

Singh et al. (2019) conducted a prospective, quasi-experimental study. This experimental group underwent integrated teaching, which consisted of problem-solving exercises and PACS. Pre- and post- tests that focused on assessing knowledge and interpretive skills were then administered. The difference between the pre- and post-test was calculated and found to be statistically significant ($p = 0.001$), substantiating the gain in interpretive skill. Chen et al. also reported that the teaching method involving the use of PACS allowed for ***"better guidance for students to develop critical thinking and systematic approach to formulate imaging interpretation and differential diagnosis"***. Similarly, Jafri et al. (2008) also reported that 64% of the students surveyed agreed that the PACS sessions prompted them to approach physical diagnosis from different angles.

By combining the use of PACS simulator and case-based learning, Qin et al. (2020) were able to mimic clinical scenarios, motivating ***"students to see, think and behave like genuine doctors"***. This helped to train the students on their diagnostic reasoning. This was proven when 25% and 55% of students who took the Smart-Class agreed and strongly agreed respectively when asked on whether their diagnostic reasoning improved, as compared to 20% and 40% respectively of the control group. One study conducted by Aufferman et al. (2015) conducted a randomised control study and offered search pattern training (SPT) to the experimental group. The SPT group was able to have additional practice with the simulated PACS workstation. This attributed to the improved performance at nodule perception and identification shown by the subjects.

4.3.2.3 Interest and Motivation

In the randomised control study conducted by Chen et al. 85% of the students felt that the interactivity of the learning activity "encouraged better personal interest in radiology, as well as satisfaction with the quality of learning". Similarly, Erinjeri and Bhalla (2006) also reported that a significant proportion of students (78%) stated that they would recommend the course to a classmate and there was an increasing trend towards interest in radiology.

Rengier et al. Conducted a study on both first year as well as fourth- and fifth-year medical students on the use of virtual anatomy. Participants of the module stated that they would urge other students to partake in the course as the assimilation of radiology led to greater keenness for anatomy. They also appreciated the opportunity to correlate the real dissection in the gross anatomy lab with the virtual dissection in the computer lab. In a study by Soman et al. (2010) 232 of the 293 participants were satisfied with using StudentPACS modules as a form of self-directed learning material and that ***"they would use StudentPACS modules for learning different topics in the future"***.

92% of the survey respondents in a study by Smith and Boscak reported that they were very likely to recommend the elective to others. The participants valued the versatility of self-directed learning that Pacsbin provided in combination to the regular interactive faculty sessions, as they were ***"similarly effective when compared to a traditional radiology rotation".***

4.3.2.4 Application to Clinical Practice

In an open-ended survey conducted by Erinjer and Bhalla, participants had the ***"opportunity to have a glimpse of the experience of 'real radiologists' dealing with a case"*** and were able to understand the role of a radiologist in synthesising imaging data with clinical information and radiologic images to form a diagnosis and impact clinical management. This finding was similarly reported by Huang et al., as the students were able to gain access to the practitioners' perspective, become part of the radiology team and gain a sense of purpose within the community. Jafri et al. implemented small group PACS sessions facilitated by a radiologist. This was to simulate the working environment that students would come across during their clinical attachments and to teach a step-by-step method to address frequent clinical problems. They were able to fulfil this aim as students stated in an open-ended survey that ***"it is good to start integrating material that we will need to know on wards and also to help us actually understand pathology rather than just memorise it"***. Similarly, in another study (Novelline et al., 2001), students had to give case presentations based on the images and information obtained from the departmental PACS. This was highly praised by the students as they felt that the skills gained from it would be "extremely useful for their future career".

4.3.3 Comparison with Didactic Lectures

Out of the 21 articles, 6 compared the use of PACS with traditional lessons consisting of lectures and static images shown during the lectures or in textbooks. In the study by Chen et al., students in the experiential group were able to utilise PACS to do basic image manipulation whereas those in the control group were only able to view typical imaging layers via PowerPoint and Word documents. The basic skills of choosing the appropriate window level and width and reconstruction methods were taught only in theory. In the assessment conducted, the experimental group exhibited significantly higher scores than the control group ($p < 0.05$). The study results also supported that reading a contiguous scan enhanced the students' comprehension of anatomy. The "Look Ahead" technique used in the study by Huang et al., allowed students to view the images prior to making their own observations and conclusions, in contrast to the current passive learning where students merely observed a preceptor interpreting imaging study. The "Look Ahead" technique was identified with statistically significant increased student reported interest, engagement with the case, educational value of the experience and memorability of the case in comparison to the current standard. In another study (Singh et al., 2019) the topics in radiology were split into two. The first part was taught using innovative methods and the second part was taught by the conventional lecture method. Irrespective of the teaching methods, the students' knowledge and interpretive skills were enhanced. However, when the innovative teaching method was in use, the increase in scores for interpretive skills was higher and statistically significant. However, the study failed to conduct an assessment on the surveys in regard to the students' satisfaction of the different teaching methods. Soman et al. Compared medical students' impression of learning from StudentPACS modules with their personal experience of learning radiology from textbooks or static images. Out of the 285 students, 257 of them found StudentPACS modules to be either equivalent or better than learning from static images or textbooks. Similarly in the study by Rengier et al., students agreed that the integrated hands-on approach course had additional benefits as opposed to the traditional course. The accordance was higher among the first-year medical students compared to the second-year students. In the study by Qin et al., the Smart-Class group incorporated practice based-learning using PACS display workstations and DICOM viewer. The Smart-Class group achieved a higher mean quiz score ($p < 0.001$) than the Traditional group. 98.2% of the Smart-Class group preferred DICOM image viewer over JPEG images as a learning tool, and 50.9% of the traditional group agreed with the Smart-Class group on the same learning tool.

4.4 Discussion

Studying radiology and anatomy through lectures and static images can be helpful in recalling information and teaching basic imaging skills. However, reading textbooks and listening to lectures are passive forms of learning. Although it still allows for retention of knowledge, simulating an experience or participating in discussions allows for active learning (Bernardo & Malinowski, 2005). This helps in improving learning effectiveness and one example of this would be the implementation of PACS training. Although there have been studies conducted that evaluate the effectiveness of PACS training, there has been no systematic review conducted on it. Hence this review assessed the impact of implementing PACS training on trainees.

The effectiveness of PACS training can be assessed using the Sloan Consortium pillars of quality education which includes access, student and faculty satisfaction, learning effectiveness and cost (Moore, 2005). The hospital and seasonality of cases can influence the types of cases trainees get to see (Bernardo & Malinowski, 2005). With access to patient's cases in PACS, trainees can view and learn from case types that they might not have been exposed to during their clinical rotations. PACS as a form of medical media can also directly guide the learning effectiveness as it accommodates to the various learning styles of students as well as facilitating active learning (Bernardo & Malinowski, 2005). Access and learning effectiveness can contribute to student satisfaction as proven by the results of this review.

PACS training is also able to simulate real life situations and make the trainees feel like healthcare professionals. This allows the trainees to analyse the situation, think critically and form differential diagnosis. Not only does it allow for the trainees to problem solve, but also understand the whole PACS as they utilise the various functions of it. This form of a learning environment helps to trigger and maintain interest, by simulating the trainees to self-generate questions for a better understanding of the situation as well as acquiring and organising their newfound knowledge of the topic (Renninger & Hidi, 2016). With the new knowledge and critical thinking skills gained, trainees can adapt to and tackle challenging situations (Almeida & Franco, 2011).

The emergence of COVID-19 pandemic has also taught us the importance of the need for online teaching tools. With the cancellations of clinicals, schools have had to restructure their curriculum to ensure that students are still able to experience and gain the necessary knowledge. By utilising PACS as an online learning and teaching tool, it prompts the construction of meaningful and engaging remote learning. It is also easily accessible as the students only need to be connected to the internet to be able to review cases on PACS. With the rapid expansion of medical knowledge and introduction of new technology, it is crucial for HCP to keep their medical and clinical knowledge and skills up to date to be able to care for their patients effectively (Tagawa, 2008). This requires life-long learning and institutions should provide opportunities to foster self-directed learning through various avenues such as motivation and problem-solving skills.

When implementing PACS training, one of the concerns that instructors had was that trainees would be distracted due to the computers. As the computers are connected to wireless networks, it's possible for trainees to access the web, distracting them from their work. However, in the study by Koestner et al., most of the instructors (67%) did not observe increased distraction of the students due to the computers, while 33% of the instructors were undecided. Instructors mostly have access to a master computer where they can view the trainees' computer screens and therefore be able to monitor the computer usage.

4.4.1 Strengths and Limitations

This review is the first of its kind to report on the impact of implementing PACS training on trainees. This review includes articles from various countries allowing for more diverse results. The results obtained from the various studies support the conclusion that PACS training has a positive impact on trainees. However, some of the limitations are the small sample sizes and biases stated in the studies. Databases such as ScienceDirect and Google Scholar were not used due to keyword restrictions, and only studies in English were used in this review. This may have resulted in possible relevant studies being missed out. Finally, there were no published systematic reviews on PACS training on trainees that we could compare our results with.

4.4.2 Future Considerations

The studies in this paper mainly consisted of medical students, residents, and nursing students. Future research could be conducted on allied health students in radiography, physiotherapy, and occupational therapy as a varied sample population would provide a more valuable dataset. An initial study can be conducted using two research method designs; quantitative test and an interview. Researchers could consider inviting SIT Year two DR students, who have learnt the foundation of RPACS in their module, to participate in the study after their clinical placement in Trimester 2. Data collected could be helpful in evaluating the extent of student's knowledge on PACS in a clinical setting and achieving a more in-depth understanding of their perspectives on learning PACS respectively. Further studies can be carried out using the various allied health students under SIT. Local studies conducted would also help us to understand the student's satisfaction and views on PACS training, allowing institutions to find ways to improve and provide the best learning environment for the students.

Currently in SIT, only diagnostic radiography students have hands-on experience using PACS within the university during their second year. In the future, exposing radiation therapy students to PACS should also be considered. Radiation therapy is an image-based treatment, and radiation therapists must constantly review images during a patient's treatment delivery as well as when planning the treatment (Law & Huang, 2003). By exposing PACS to the students, they can familiarise themselves with the workspace as well as the images before their clinical attachments, allowing them to feel more confident and prepared as seen by the results of this review.

4.5 Conclusion

This systematic review highlights the following themes which seem to be necessary for the success of PACS training: Self-efficacy, Skills of Inquiry, Interest and Motivation, Application to clinical practice, Radiological Science and Technology and Utility of PACS. Overall, positive feedbacks were received from the shortlisted studies. The trainees demonstrated an increased level of self-confidence and critical thinking skills. They also found imaging content and processes and PACS knowledge useful for their clinical practice, showing high interest in their training. Furthermore, trainees were also satisfied with the features and interface of the PACS, as it aided them in their understanding of difficult materials and improved their work efficiency. These findings suggest that implementing PACS would be effective, and institutions should consider implementing PACS training as part of their medical curriculum.

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