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Development and Testing of a Web Application to Improve Entry-to-Practice Pediatric Nursing Competencies: A Proof-of-Concept Study

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Nurse educators can design technology-enhanced learning supports to prepare graduates to meet entry-to-practice (ETP) competencies and pass licensure examinations. The purpose of this study was to develop and test a proof-of-concept web application (Web App) to facilitate understanding of ETP competencies, and to explore the Web App's potential to improve performance on NCLEX readiness tests. We developed and evaluated the Web App in two stages. We focused on identifying important technical considerations involved in creating the Web App, developing learning content, and creating self-testing questions for learners in the Pilot phase. In the full-scale implementation phase, participants accessed the Web App content and self-testing questions and completed a study questionnaire and knowledge test; a subset of participants completed the NCLEX readiness test. Web App participants demonstrated a small-medium effect size on the knowledge test for overall score (d=0.39) and knowledge transfer (d=0.44) when compared with non-participants. There was no significant difference in performance on the NCLEX readiness test between participants and non-participants. This proof-of-concept study supported the development, implementation, and evaluation of a Web App to promote learning of ETP competencies. Future research directions include development and evaluation of technology-enhanced learning aids that align with nursing curricula and ETP competencies.

Keywords: *education technology, web application, competency-based education, entry-to-practice competencies*

Background

Over the past decade, there has been a global shift in nursing education with an increased focus on learners' preparedness for nursing practice and attainment of entry-to-practice nursing competencies (Arcand and Neumann 2005). In 2003, the International Council of Nurses (ICN) defined Entry-to-Practice (ETP) Competencies as key competencies a generalist nurse must achieve by the time they enter nursing practice (Black et al. 2008). In 2004, ten Canadian nursing regulatory bodies developed ETP Competencies for graduates of registered nurse education programs in order to promote consistency across different Canadian jurisdictions (Black et al. 2008). The resulting document from this Jurisdictional Competency Project summarized 119 competencies under the following five categories: (1) professional

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responsibility and accountability; (2) knowledge-based practice; (3) ethical practice; (4) service to the public; and (5) self-regulation (Black et al. 2008).

In Ontario, the provincial regulatory body for registered nurses (RNs), the College of Nurses of Ontario (CNO), used the Jurisdictional Competency Project to create 100 ETP Competencies which were subsumed under the same five competency categories (Entry-to-Practice Competencies for Registered Nurses, 2014). A guiding principle of the CNO's ETP Competencies is that baccalaureate programs will prepare new graduate RNs to "practice safely, competently, and ethically with people… across the lifespan" (CNO 2014, p. 4). As such, undergraduate nursing programs in Ontario must prepare graduates who are capable of caring for individuals of all ages.

ETP Competencies to Competency-Based Education

The rise of ETP Competencies in Canada and other parts of the world has led to curricular changes in nursing education programs. Provincial nursing regulatory bodies have used the Jurisdictional Competency Project to develop specific ETP Competencies and competency measures, recognizing the need to convey to educational institutions that a curriculum designed to meet these competencies should form the basis for accreditation of their degree program (CNO 2014).

With the ETP Competencies framework in mind, baccalaureate nursing education programs have begun to explore a competency-based education (CBE) model. CBE is an educational model that explicitly outlines the skills and abilities required in a competent practitioner (Chapman 1999). While, historically, a criterion for accreditation was for students to complete minimum required clinical hours in the practice setting, CBE proposes that achievement of ETP Competencies should serve to accredit nursing programs. This move to a competency-based approach to degree completion is not exclusive to nursing. Other health professional education programs such as medicine, occupational therapy, and physical therapy, have also developed outcome-based ETP Competencies for graduates of their respective disciplines (Verma et al. 2006). In Canada and the United States, graduates of registered nursing programs must also pass the National Council Licensure Examination for Registered Nurses (NCLEX-RN) for successful licensure and entry to practice.

Mobile, Smartphone-Based Learning Supports

To prepare nursing graduates for practice, many mobile technologies and smartphone-based learning supports have been developed over the past few decades. One such learning support is the use of mobile applications for licensure preparation, and companies such as Uworld® and Kaplan® specialize in licensing exam preparation, including the NCLEX-RN. Smartphones have a number of capabilities that can enhance learning and, specifically, support CBE in nursing and health professions education.

Digital games for medical students and residents, especially through virtual and/or augmented reality, are being used as training tools to help simulate difficult

environments and help in developing key practice competencies. For example, games can be used in surgical training to improve hand-eye coordination and reflex time (Graafland et al. 2012, Rosenberg et al. 2005). Simulation-based activities can also fulfil a variety of other educational goals, including providing repetitive practice, range in difficulty, multiple learning strategies, a controlled learning environment, individualized mastery plan, and defined outcomes (Guze 2015). Opportunities exist for smartphones to be applied in the context of nursing education to further a CBE model for undergraduate nursing.

Nursing Pediatric Clinical Experiences

Pediatric nursing is a practice area with high student interest but limited clinical placement availability. Due to the limited availability of these pediatric placements, up to 65% of students at one of our institutions do not receive a clinical placement in pediatrics. However, pediatric nursing knowledge and skills are still tested on the NCLEX-RN, which all baccalaureate-prepared nursing (BScN) graduates need to successfully complete in order to be a Registered Nurse in Canada. Anecdotal reports suggest that even though pediatric content is woven through the program's theoretical course content, students subsequently perform poorly on pediatric-related NCLEX-RN content and demonstrate consistently weak performance on the portion of the Health Education Systems Incorporated (HESI) exam pertaining to pediatric nursing practice. The HESI exam is a computer-adaptive test that mimics the NCLEX-RN testing format and has been used by BScN programs and learners to assess their preparedness for the NCLEX-RN.

These anecdotal findings suggest a need for creative and effective approaches to address students' gaps in pediatric nursing exposure, knowledge, and practice, with the goal to help students achieve ETP competencies in pediatrics and to be successful on the NCLEX-RN. In a pediatrics residency program in Abu Dhabi, drastic changes were initiated after pass rates on the Arab Medical Board examinations revealed that the pediatric residency program scored consistently below the national average; a competency-based training reform brought about significant improvements in educational and patient care outcomes (Ibrahim et al. 2015). Simulation-based learning and technology-supported learning is being used more and more frequently in health professions education programs. Therefore, we saw an opportunity to develop and test a proof-of-concept web application which would provide a technology-supported learning experience to help students achieve the required ETP competencies in pediatric nursing.

Purpose

The purpose of this study was threefold:

1) To create a proof-of-concept, smartphone-accessible web application (Web App) that would support student development of pediatric nursing ETP competencies.

2) To evaluate the Web App for effectiveness of content delivery, knowledge development, and self-testing with respect to the CNO's ETP competency domains.
3) To explore the Web App's potential to improve student performance on NCLEX-readiness tests such as the HESI.

Research Ethics Approval

Research Ethics Board approval for this study was obtained from both universities prior to study implementation. All participants provided written and informed consent to participate.

Methods

Development of the Web App - Technical Considerations

The first phase of this project was to design a proof-of-concept web application that would support learner development of pediatric nursing ETP competencies. The Web App design phase occurred between September 2016 and March 2017. Important technical decisions needed to be made before content could be added. We first needed to identify a platform that could host the content we intended for learners to access. We decided early in the project design phase to create a web application, as opposed to a native app, because a web application could be used with any internet-enabled computer, tablet, or smartphone device. We researched several website building and hosting services, and selected Squarespace® because of the simplicity, ease-of-use, and modern design of its website building services.

Next, the Web App domain name www.MyCAPnurse.com was selected, with the CAP acronym standing for "Competence, Assessment, Practice." Using the CNO's ETP competencies as the guiding framework, all authors curated content and developed learning modules that covered pediatric content within the five CNO ETP competency domains: Professional Responsibility and Accountability, Knowledge-Based Practice, Ethical Practice, Service to the Public, and Self-Regulation.

We reviewed the Canada Copyright Act and the University's Fair Dealing Policy to ensure that any publicly-available pediatric nursing content accessed on www.MyCAPnurse.com was appropriate for use. Pediatric content was curated and adapted to provide a broad and balanced representation of the different ETP competency domains. Publicly-available resources, as well as online learning videos, articles, and pediatric content created by the research team, were collated, evaluated for appropriateness and quality, and matched to one or more ETP competencies. All content was formatted for the platform by our site developer and research assistants.

One of the goals for the Web App was to provide opportunities for students to test their own learning of the content they reviewed on the Web App. Therefore,

we selected the 4Screens® Engageform platform which allowed us to embed quiz questions at the end of every learning module. Up to ten (10) multiple choice and/or short answer quiz questions for each learning module were developed, and all quiz questions provided learners with immediate feedback to their responses. The Web App content, including the learning modules and quiz questions, was reviewed by all members of the research team, several of whom had expertise in pediatric nursing.

Pilot Implementation

A pilot cohort (n=33) of senior-level nursing students at one of our study sites (i.e., one university) was recruited in April 2017. Pilot participants were allowed to review the Web App content and quizzes. At the end of 12 weeks, participants were asked to provide feedback on the Web App's mobile accessibility, visual appeal, and module content quality. Furthermore, participants were asked how much time was spent on the Web App. This feedback was reviewed, and the research team used the pilot participants' feedback to refine the Web App platform and content in preparation for full-scale implementation.

Web App Platform Refinement

Based on the pilot phase and subsequent feedback, significant revisions were made to www.MyCAPnurse.com. Additional content modules and quiz questions were created. In the pilot phase, we created 13 learning modules and 68 quiz questions. We added 9 more learning modules and 94 more quiz questions for the full-scale implementation phase (see Table 1).

There was a significant expansion of content with respect to the Service to the Public and Self-Regulation ETP competency domains. While much of the content in these two domains did not specifically cover pediatric nursing practice, we curated and developed learning modules to reflect a pediatric nursing practice lens. Additional quiz questions were added to existing learning modules to emulate the NCLEX-RN exam's testing format. The visual layout of www.MyCAPnurse.com was also refined to ensure that learning activities and modules were easier to find, and the Web App was easier to navigate, both on a laptop/desktop computer and on tablet/mobile devices.

Table 1. *Web App Learning Module Topics*

Pediatric Advanced Life Support (PALS) Resuscitation
Congestive Heart Failure
Heart Murmurs
Situation, Background, Assessment, Recommendation (SBAR)
Pediatric Septic Shock Clinical Practice guidelines
ABCDs of Pediatric Assessment
Medication Errors in Pediatrics
Medication Safety in Pediatrics
Safe Medication Use in the ER
Status Epilepticus Clinical Practice Guidelines
Pediatric Assessment Clinical Practice Guidelines

Pediatric Procedures Clinical Practice Guidelines
Developing SMART Learning Goals
QA Program Learning Plan
Ethical Issues for Nurses
- Therapeutic Lying/Deception
- DNR Ethics
- Company Policy and Best Practice
Self-Regulation
- Public Protection
- Confidentiality
- Professional Responsibility

Full-Scale Web App Implementation

A larger sample of nursing students at both universities (n=72) was recruited in January 2018 to participate in the study and no students who participated in the pilot phase enrolled in the full-scale implementation phase. Of the 72 participants who enrolled in the study, only 46% (n=33) accessed and perused the enhanced and refined version of the Web App over the span of four months. A research assistant sent participants bi-weekly email check-ins. These messages highlighted the various features www.MyCAPnurse.com offered and were intended to promote students' use of the Web App during the study period.

Participant feedback on the user interface, ETP competencies, and self-reporting data was collected through email correspondence throughout the four-month duration. At the end of the four-month study period, all participants (including those who did not access the web application during the study period) completed a Web App questionnaire and knowledge test. The Web App questionnaire gathered users' experiences with www.MyCAPnurse.com and both qualitative and quantitative data were collected. The knowledge test consisted of 32 multiple-choice questions (MCQs) that assessed pediatric content knowledge. Half of the MCQs were questions that had been accessible to Web App users through www.MyCAPnurse.com, while the remaining half were new MCQs for all participants. We structured the knowledge test this way, with half of the questions being familiar and half of the questions not familiar, to assess for Web App participants' knowledge transfer.

A small subset of participants also completed the HESI examination. The academic performance of all participants was analyzed and compared across the two cohorts (Web App users vs non-users).

Results

Participant Evaluation of Web App and Perceptions of Knowledge Acquisition

Participants were asked to rate the Web App on a 7-point Likert scale for content and effectiveness of exposure to pediatric ETP competencies (see results in Table 2). In the qualitative feedback collected, participants indicated that the module content was relevant to nursing practice and helped them learn more about the pediatric ETP competencies required for nurses in Ontario. However, participants

wanted access to more NCLEX-RN-style practice questions. Web App participants also commented that the module content was not accessed as frequently as they desired due to a number of factors; school workload was the most frequently cited barrier.

Table 2. *Mean Scores by Web App Participants for Web App Content and Various Descriptors (7-Point Likert scale*)*

	Mean Score (SD)
Usefulness for learning CNO ETP competencies for pediatric nursing	4.64 (1.27)
Relevance of quiz questions to module content	5.03 (1.18)
Relevance of quiz questions to CNO ETP competencies	5.00 (1.12)
Relevance of web app to ***Evidence-Informed Knowledge*** of pediatric nursing**	4.79 (1.14)
Relevance of web app to ***Collaboration with Clients*****	4.82 (1.29)
Relevance of web app to ***Communication and Collaboration with Members of Health Care Team*****	4.85 (1.20)
Relevance of web app to ***Professionalism*** in nursing practice**	5.18 (1.26)

*Note: A 7-point Likert scale for the questions was used, with a score of 1 meaning "not at all useful/relevant" and a score of 7 meaning "extremely useful/relevant".
**Note: These are Canadian Association for Schools of Nursing (CASN) Competencies.

Knowledge Test Results Summary

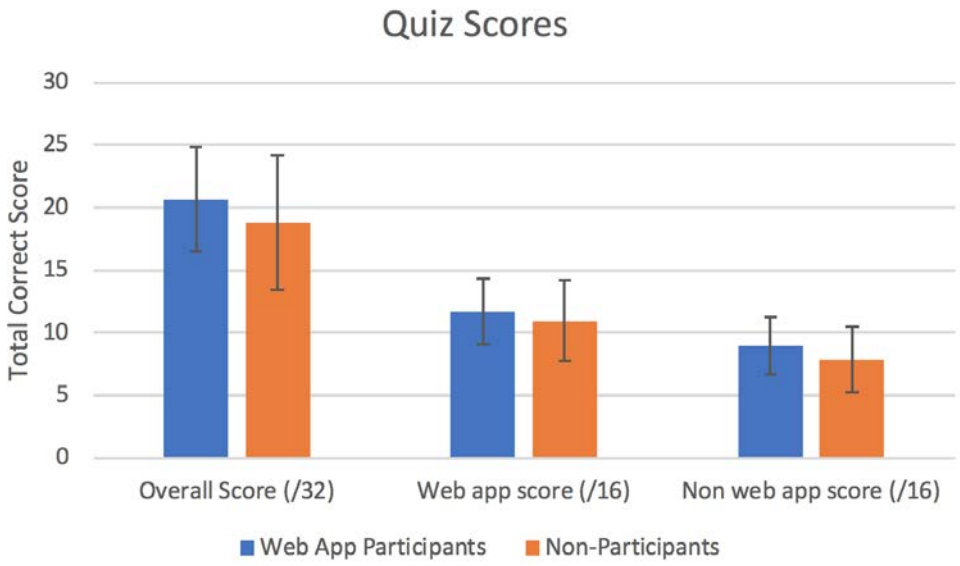
The knowledge test component of the final questionnaire consisted of 32 MCQs. To test both learning recall from the Web App and knowledge transfer, 16 questions were repeated from the Web App content and would have been familiar to participants, while an additional 16 questions were new for all respondents. Questions were paired so that test content between the old and new questions would be consistent. For example, a Web App question on normal infant heart rates would be paired with a newly developed question on the normal respiratory rate range for infants.

Our hypothesis was that Web App participants would score significantly higher on the familiar Web App questions when compared with non-Web App participants. Furthermore, we also hypothesized that, if reviewing the Web App content facilitated transfer of learning, Web App participants would score higher on the unfamiliar pediatric questions when compared with non-Web App participant scores.

SPSS Version 25 was used for the statistical analyses. Overall, Web App participants scored 20.70 (SD=4.16) questions correct out of 32, while non-participants' average score was 18.82 (SD=5.37). An independent samples Kruskal-Wallis test yielded an H=2.18, p=0.14; effect size d=0.39. On the familiar/recall Web App questions, participants scored 11.73 (SD=2.63) out of 16, while non-participants scored 10.95 (SD=3.24); H=0.835, p=0.36; effect size d=0.26. On the non-Web App questions assessing knowledge transfer, participants scored 8.97 (SD=2.31) and non-participants scored 7.87 (SD=2.62); H=3.16, p=0.076; effect size d=0.44. These results are presented in Figure 1. Subgroup analyses performed

based on university program site and based on whether the participant had completed a previous pediatric clinical placement did not yield any statistically significant differences in Web App test performance.

Figure 1. *Results of the Knowledge Test, Showing an Overall Score (Out of 32), a Score of Repeat Web App Questions (Out of 16), and a Score of Non-Web App Questions (Out of 16)*



HESI Results

A small subset of study participants elected to complete the HESI exam at the end of the study period. Because this was an optional offering, 18 students completed the HESI, 4 of whom were Web App participants. The results showed that Web App participants received a mean overall HESI score of 786.50 (SD=166.96), while non-participants scored 809.57 (SD=156.67). For reference, a HESI score of 850 or greater is considered "Acceptable". The independent-samples Kruskal Wallis test demonstrated H=0.229, p=0.63. For the HESI pediatric scores, Web App participants scored a mean of 721.75 (SD=97.70) and non-participants scored 754.43 (SD=258.96); H=0.00; p=1.0.

Discussion

This study provided important insight into the process of developing a Web App for use in nursing education and CBE. In creating and evaluating this proof-of-concept Web App, we had to make important technical and content decisions that would lead to successful Web App development, implementation, and evaluation. Useful information gained throughout the Web App development process will be presented here.

Development Process - Choosing to Create a Web Application

The way we interact with technology, including smartphones and apps, is continually and rapidly evolving. The decision to develop a web application to deliver modules on ETP competencies was a sound choice in 2016, when myCAPnurse.com was created. A web application maximized accessibility and provided participants the freedom to access the content through their preferred medium, rather than restricting them to certain platforms or operating systems. However, a web-based application has to maintain an internet connection to use and may, paradoxically, restrict access, a shortcoming that native applications have overcome (Vaupel et al. 2018). The convenience of a native app (e.g., easier to launch) may also encourage app use more than web applications on mobile devices. Native app development requires creators to have more technical competence and must be tailored to the specific smartphone platform. Website building companies like Squarespace® guide web app development and this site became our preferred choice for the Web App we created. While creating a native app would require more computer programming knowledge and capability than a web application, it may the more popular choice for end users, as smartphone application use evolves.

Canada Copyright Act and University's Fair Dealing Policy

To create our proof-of-concept Web App, it was important to understand the policies around content use, given that the learning module content we curated greatly relied on publicly-available pediatric nursing content. Prior to developing or importing content onto the Web App, we needed to understand and comply with the Canada Copyright Act and the University's Fair Dealing Policy in the content we added to the Web App. Another direction we could have taken was to develop most, or all, of the Web App content independently. However, given the short timeline we had for the development phase, we needed to work with existing pediatric nursing content. We also felt that curating publicly-available content could be beneficial for student learning (e.g., news articles could provide diverse perspectives on current issues.)

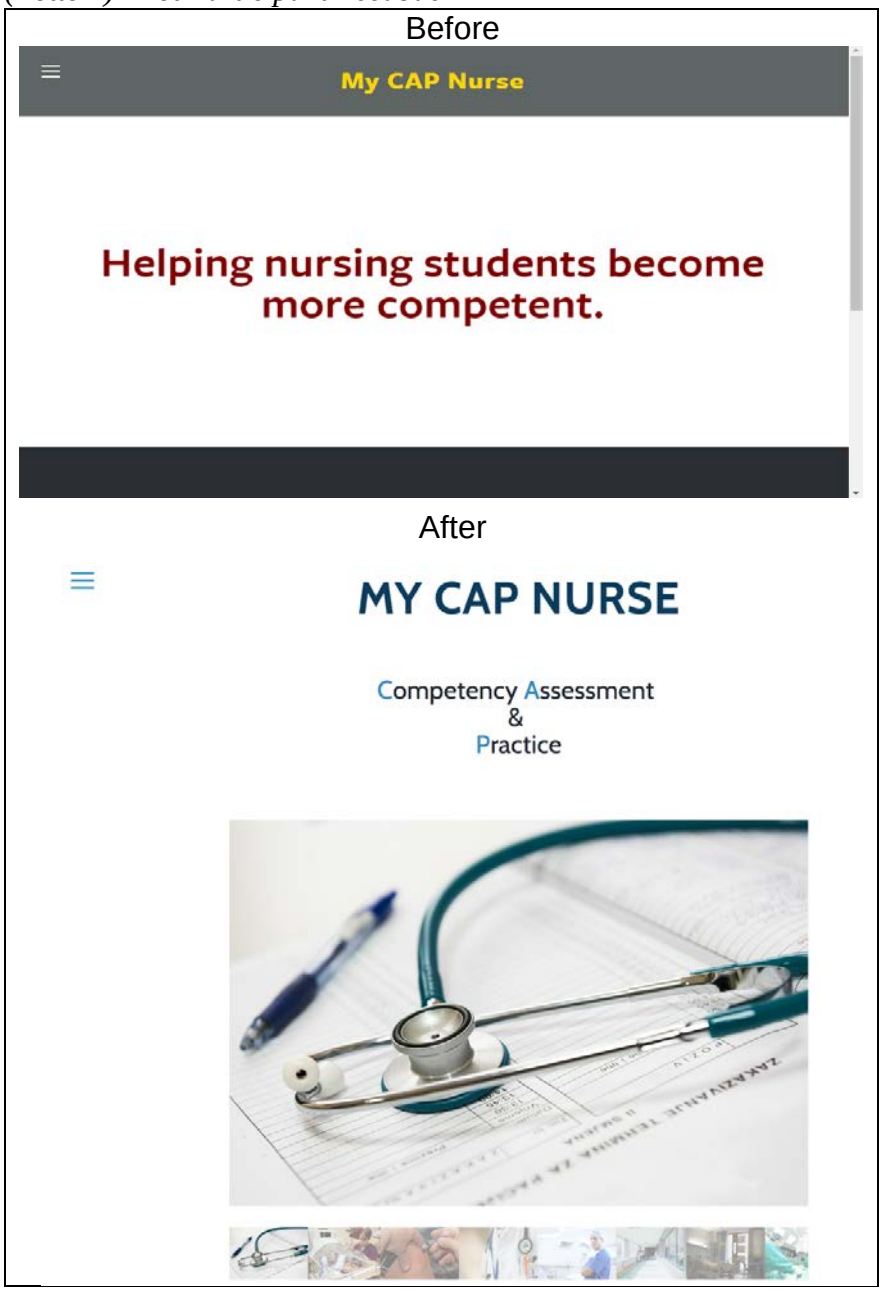
Purpose of Modules

When undertaking the design of an ETP competency-based Web App, it was important that any modules created have clear learning objectives and purpose and would tie in to the ETP competencies. To meet this goal, our team linked learning activities and modules to specific ETP competencies and each learning module highlighted the connection. Not only did this provide learners with exposure to the ETP competencies required by the provincial nursing regulatory body, it also ensured learners knew what knowledge and skills they would be expected to develop within that specific module. This is consistent with a competency-based educational approach (Pijl-Zieber et al. 2014).

User Interface (UI) Considerations

Visual appeal was a very important consideration during the Web App refinement process. In the pilot implementation, some of the participants identified the layout of the Web App as the reason they used the app less frequently. Significant visual overhauls were subsequently made to ensure that the web app was aesthetically pleasing and that the visual appeal did not take away from the overall experience (see Figure 2 for screenshots of the home page before and after pilot feedback).

Figure 2. *Example of www.myCAPnurse.com Home Page Before (Top) and After (Bottom) Pilot Participant Feedback*



A related UI point of consideration is the ease of use and navigation of the Web App. Qualitative feedback in the pilot implementation indicated that the initial version of the Web App was not easy to navigate. Through refinement, we added a Contents/Index page, as well as a search bar, to ensure that it was easy to find one's way around the Web App. Great care was also taken to ensure that the Web App was always simple and intuitive to use. The aim was to prevent "visual clutter", overcrowding of information, and minimizing the number of steps (or "clicks") required to access module content.

ETP Competency Development

In the pilot phase, participants responded that the Web App and activities were useful in learning the CNO ETP Competencies for pediatric nursing. One Web App participant in the full-scale implementation phase commented, "I felt that [...] the module content was very relevant to nursing practice and helped me learn more about the entry to practice competencies that are required for nursing in Ontario." However, another participant noted that the "app wasn't intuitive." Overall, participant feedback suggested that the web app was useful in providing exposure to the students and helping them learn about the ETP competencies, but still challenging to navigate.

Study Questionnaire, Knowledge Test and HESI Performance

Within the first week of posting the study announcement at both universities, we received over 120 students who signed up to participate in the study. All interested individuals were provided the link to the Web App and were encouraged to use the Web App as often as desired. A research assistant sent participants bi-weekly check-in emails, and these messages highlighted the various features of www.myCAPnurse.com. However, at the conclusion of the study, only 33 of the original Web App participants completed the final study questionnaire and pediatric Web App knowledge test questions.

There were no statistically significant differences between Web App participants and non-participants when it came to both the repeat knowledge test questions (from the Web App) and the new questions. We expected a significant difference in performance when it came to the repeat knowledge test questions, given that the Web App participants would have been exposed previously to those questions, while non-participants would not. Interestingly, both groups performed better on the repeat questions than on the new questions, although it was not statistically significant. We did, however, note a moderate effect size of 0.44 for the Web App participants who demonstrated improved performance on new, or unfamiliar, test questions when compared with non-participants. This suggests that pediatric Web App users may have had some transfer of pediatric knowledge after use of the Web App.

On the HESI, there were no significant differences in performance between the Web App participants and non-participants. While we expected Web App participants to perform better on the pediatric portion, but not necessarily on the

overall HESI, our data was underpowered to detect any statistically significant differences between groups, if indeed the Web App use supported pediatric HESI performance.

While we recruited more participants than our sample size calculations required, a significant limitation to our findings is that we were under-powered to detect the outcomes of interest for participants who used the Web App. This is especially true for the HESI, where there were only four Web App participants and 14 non-participants. For the Web App knowledge test, we had only 33 web app participants and 39 non-participants. Sample size calculations required 80 study participants, half of whom would use the Web App. A two-point difference on the Web App Test result score would yield a moderate effect size of 0.5. To achieve the same moderate effect size of 0.5 on the HESI, we focused on the HESI pediatric sub-scores as our primary outcome, instead of the overall HESI score. We required 30 total participants, 10 of whom were Web App users, to achieve the minimally acceptable score of 850 as compared with non-Web App users who we anticipated would achieve an average score 750.

Additional Considerations

Disconnect Between ETP Competencies and NCLEX Examination Preparation

A possible reason for the poor uptake of the Web App by participants could be the disconnect between the relative importance ascribed to learning about the ETP Competencies when compared to the need to prepare for the NCLEX licensure examination. The Web App focused on helping students understand ETP competencies in pediatric nursing because the study team felt that pediatric nursing content was an area of the nursing curriculum where students wanted more exposure. The focus of the Web App was on ETP competencies, and all learning modules made explicit connections to specific ETP competencies. Focusing on helping students develop ETP competencies might not necessarily translate to better outcomes on practice-based exams like the HESI, and participants may have used the Web App less because they did not see the connection to the HESI or NCLEX.

Minimal Time Spent on App

The majority of Web App participants (n=26) spent a total of 0-3 hours/week reviewing the learning content on the Web App during the study period. Two participants reported 3-6 hours/week of review, three spent 6-9 hours/week, and two devoted 10+ hours/week to web app review. The minimal time spent by most of the Web App participants would prevent them from reviewing the ETP Competencies learning modules in depth. Furthermore, because the MCQ and short answer self-testing questions were embedded at the end of every learning module, this would also explain why Web App participants performed similarly to non-participants on the repeat questions of the knowledge test.

Curriculum Integration and Motivation

If Web App content was more directly linked and integrated to the BScN program curricula or linked to evaluation measures within the course curricula at the two university sites involved in this study, students would likely have greater incentive to review the Web App frequently and regularly. Those interested in future Web App or technology-enhanced learning supports would benefit from connecting their work to nursing program curricula and to evaluation measures within the program curriculum. Our results suggest that participants are less motivated to engage in learning that is perceived to be future-oriented (e.g. understanding ETP competencies) and not directly connected to their current course of studies and/or licensure examination preparation. This could be due to the students' motivation for learning. Learners who are intrinsically motivated to learn tend to be more engaged, retain information better, and are generally happy; in contrast, those students who are extrinsically motivated by some outside force may not be as likely to seek additional opportunities to learn when they are not directly related to the extrinsic objective (Hanus and Fox 2015).

Conclusion

The manner with which students engage technology and mobile applications for learning continues to evolve and change. This proof-of-concept study supported the development, implementation, and evaluation of a Web App to promote learning of ETP competencies for pediatric nursing practice. Future research directions include continued development and testing of technology-enhanced learning aids that align with nursing program curricula, entry-to-practice competencies, and future licensure examinations. Furthermore, education researchers are ideally positioned to develop technology-supported learning aids that promote intrinsic and extrinsic motivators for use and that could evolve with technological advances in smartphone and mobile-supported learning and developments in the education research literature.

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