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ORIGINAL ARTICLE

E-Learning with virtual teammates: A novel approach to interprofessional education

Maja Djukic¹, Jennifer Adams², Terry Fulmer³, Demian Szyld⁴, Sabrina Lee⁵, So-Young Oh⁵, and Marc Triola²

¹College of Nursing, New York University, New York, NY, USA, ²School of Medicine, New York University, New York, NY, USA, ³Bouve College of Health Sciences, Northeastern University, Boston, MA, USA, ⁴New York Simulation Center, New York, NY, USA, and ⁵Division of Educational Informatics, New York University, New York, NY, USA

Abstract

The Institute of Medicine identified interprofessional education (IPE) as a key innovation for achieving the triple aim of better care, better outcomes, and reduced healthcare costs. Yet, a shortage of qualified faculty and difficulty with aligning learners' schedules often prevent sustainable and scalable IPE. A virtual IPE intervention was developed to circumvent these barriers and compared to a blended-learning IPE intervention. We used a pre-test and post-test design with two comparison interventions to test the effects of these IPE interventions on changes in teamwork knowledge, skills, and attitudes. The interventions were delivered to pre-licensure learners at a large, metropolitan medical and a nursing school. We used one-sample and independent-sample t-tests to analyze data from 220 learners who received the blended-learning intervention in 2011 and 540 learners who received the virtual learning intervention in 2012. The students in the blended-learning intervention did not significantly ($p < 0.05$) outperform the students in the virtual learning intervention for any of the measured outcomes, except for medical students' attitudes around team value. Virtual IPE learning is an effective, scalable, and sustainable solution for imparting foundational teamwork knowledge in health profession students.

Introduction

Interprofessional education (IPE) is defined as “members of more than one health or social care profession (or both) learning interactively together, for the explicit purpose of improving interprofessional collaboration or the health/wellbeing of patient/clients (or both)” (Reeves, Perrier, Goldman, Freeth, & Zwarenstein, 2013, p. 4). The World Health Organization (WHO, 2010), The Institute of Medicine (IOM, 2013), stakeholders across diverse professions and countries (Frenk et al., 2010; Interprofessional Education Collaborative [IPEC], 2011), and major funders (Thibault, 2012) have all endorsed IPE as a vital link for achieving the triple aim of better health, healthcare, and lower costs (U.S. Department of Health and Human Services [DHHS], 2013). There is an increasing body of evidence linking IPE to improved outcomes for people with diabetes, decreased clinical error rates in emergency department (Reeves et al., 2013), and lower surgical mortality (Neily et al., 2010). Despite the importance of IPE, shortages of faculty competent in IPE, coupled with difficulty in aligning students' schedules are key factors impeding IPE implementation (Abu-Rish et al., 2012) that is systematic (i.e. accessible to all students as part of mandatory curricula), sustainable (i.e. persisting in spite of faculty turnover or after start-up funding is cut) and scalable

Keywords

Interprofessional education, medical students, nursing students, teamwork, virtual learning

History

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(i.e. easily distributed to a large number of students without significant increases in resources required to deliver a program). Use of e-learning and virtual teammates to implement IPE has the potential to overcome these barriers.

Use of e-learning (Feng et al., 2013) and virtual patients (Cook, Erwin, & Triola, 2010) has been shown to be effective for improving health professions students' learning for a variety of clinical topics. However, little is known about the effectiveness of e-learning with virtual teammates for IPE. The purpose of this study was to examine the impact of two IPE interventions on improving learners' knowledge, skills, and attitudes for interprofessional teamwork and collaboration.

We compared the outcomes from two intervention approaches of an IPE program. In the blended-learning IPE intervention, we grouped actual medical and nursing students into teams to collaborate in-person and online to complete IPE coursework. In the virtual IPE intervention, we replaced each student's teammates with a pre-authored virtual team member (i.e. a virtual nursing or medical student was paired with an actual nursing or medical student). This virtual teammate contributed content and comments to the online learning environment as the actual learner went through the curriculum.

Given the advantages of virtual over blended-learning approaches in terms of scalability and sustainability, it is important to test differences in learners' outcomes between the two approaches. By comparing e-learning with traditional learning for clinically focused topics, authors of a systematic review focused on undergraduate students in health professions found that e-learning either produced significantly greater gains in

Dr. Terry Fulmer is now president of the John A. Hartford Foundation, New York, NY, USA.

Correspondence: Maja Djukic, College of Nursing, New York University, 726 Broadway, New York, NY 10003, USA. E-mail: md1359@nyu.edu

knowledge and skills or was not different in these outcomes compared to traditional learning (George et al., 2014). Additionally, in terms of attitudes toward e-learning versus traditional learning, in eight studies, there were no significant differences between e-learning and traditional learning, while one study reported student preference for traditional over e-learning (George et al., 2014). Based on the existing literature (George et al., 2014; U.S. Department of Education, 2010), we hypothesized that there would be no statistically significant differences between students who participated in the blended-learning IPE intervention compared to students who participated in the virtual learning IPE intervention on their reported teamwork knowledge, skills, and attitudes, which we measured with previously validated scales (Leipzig et al., 2002; Siegler, Hyer, Fulmer, & Mezey, 1998) and researcher-developed measures, described in detail below.

Background

Setting

The IPE program (Djukic, Fulmer, Adams, Lee, & Triola, 2012) was delivered to medical and nursing students at a large private university in an urban setting. Curriculum revisions at both the College of Nursing and the School of Medicine, coupled with strong collaboration between administrative leaders, availability of faculty champions, simulation and e-learning expertise, and substantial funding support from The Josiah Macy Jr. Foundation created a successful milieu for developing and implementing the IPE program. Additionally, both schools have a strong focus on technology and educational innovation. For example, 50% of clinical undergraduate nursing education is being delivered via simulations. Also, medical students receive up to 100 hours of simulation over four years. The College of Nursing enrolls close to 1000 undergraduate and 700 graduate students yearly, has about 60 full-time faculty, and ranks in the top five nursing schools for National Institute of Health research funding. Similarly, The School of Medicine is a leader in medical education and research, recently establishing a new curriculum with dual degree options and a 3-year pathway (Abramson et al., 2013). The School of Medicine has 1360 full-time faculty and 2175 part-time faculty. In 2013, 737 students were enrolled in the School of Medicine's MD program.

The IPE Program

An interprofessional faculty team from medicine and nursing took on the IPE challenge by developing a comprehensive, technology-enhanced IPE intervention (Djukic et al., 2012). The program integrated content from previously validated team training curricula: Geriatric Interdisciplinary Team Training ([GITT], Siegler, Hyer, Fulmer, and Mezey (1998) and TeamSTEPPS (Agency for Healthcare Research and Quality [AHRQ], n. d.). We aimed to prepare learners in key IPE competencies including: values and ethics for interprofessional practice, roles and responsibilities, interprofessional communication, and teams and teamwork (IPEC, 2011). The 1-year long, spaced curriculum had several components that were embedded into the required, formal nursing and medical school curricula. The learning outcomes and activities for the faculty-facilitated seminar, small group learning activities and the seven e-learning modules have been detailed in a previously published manuscript (Djukic et al., 2012) and are available on the program's website.

Blended-learning IPE intervention

The blended-learning intervention components included: attending a one-time 4-hour in-person faculty-facilitated seminar and

small-group learning session, plus completing five e-learning modules with actual teammates, which required them to asynchronously collaborate online (or participate in online discussions) in the first semester. Online interprofessional collaboration in the first five modules included posting and responding to comments on teamwork dynamics featured in video vignettes that were embedded in the modules. Then, students read teammates' comments to gain an understanding of cross-professional teamwork and collaboration perspectives. Each module took an average of 30 minutes to complete. The first semester activities were focused on building learners' knowledge about the importance of IPE and key IPE topics such as team members' roles and responsibilities, effective communication and conflict resolution, teamwork, and interprofessional care plan development.

In the second semester, the students completed two e-learning modules, which were focused on the application of key concepts learned in the first semester. These two modules also took about 30 minutes to complete and required asynchronous participation. The two e-learning modules featured virtual patients (Cook et al., 2010) with electronic health records including information on health and social history, laboratory values, and key complaints. The students were tasked with individually interviewing the virtual patient and writing patient care notes, then collaborating to develop a diagnosis and an evidence-based interprofessional care plan that reflected medical student's, nursing student's, and patient's perspectives. Lastly, students self-evaluated their performance by comparing their care plans with care plans developed by an expert interprofessional team, which comprised medical and nursing school faculty.

Virtual IPE intervention

The virtual learning intervention components included: completion of seven e-learning modules with virtual teammates; five modules in the first semester and two in the second semester. The sequencing and content of the modules was identical to the blended-learning cohort. This intervention did not include an in-person faculty-facilitated component and the small-group learning session. Similar to the blended-learning approach, it included the same seven e-learning modules (five knowledge focused modules and two virtual patient modules), but in this case, nursing students collaborated with computer-provided virtual medical student teammates and vice-versa. The comments and content of the virtual teammate's contributions were created by faculty who selected exemplary responses and patient care notes from actual students who participated in the blended-learning intervention in 2011.

Methods

Study design

A pre-test and post-test design with two comparison intervention cohorts was used. Data on teamwork skills and attitudes were collected using an electronic survey at 0 months and 12 months. Teamwork knowledge data were also collected using an electronic survey pre-completion and post-completion of the five e-learning modules delivered in the first semester. A comprehensive knowledge exam was administered electronically at 12 months.

Sample

The analysis included 220 learners who completed the IPE blended-learning intervention in 2011 and 540 learners who completed the IPE virtual learning intervention in 2012. The medical students in both groups were within the first 16 months of matriculation when they received the IPE interventions and the nursing students were within 16 months of graduating from

the baccalaureate nursing program. We did not collect demographic data for the students to expedite institutional research review and approval process. However, we have no reason to think that the students who participated in the study were different from the students who did not participate or that there were significant differences between the two study cohorts. That is because completion of the IPE program components, which we studied, was mandatory for receiving a passing grade in courses that were part of regular medical and nursing school curricula. Additionally, our consent rates for the study cohorts were high: 85% of medical students in the blended-learning intervention, 88% of medical students in the virtual learning intervention, 89% of nursing students in the blended-learning intervention, and 95% of nursing students in the virtual learning intervention consented.

Main outcome measures

We measured change in knowledge, skills, and attitudes using previously validated scales and researcher-developed measures. To measure changes in knowledge, we created multiple choice tests for each of the five modules. We determined the change in knowledge by comparing the mean number of correct responses to multiple choice questions from pre-test to post-test and from pre-test to 12 months. The multiple choice test questions were developed at the application level of Bloom's taxonomy (Krathwohl, 2002) and in the context of a clinical vignette case to test students' application of knowledge to real-life situations. The multiple choice tests for modules one, two, and three had eight questions each. The multiple choice tests for modules four and five had six questions each. The comprehensive knowledge exam that we administered at 12 months included the vignette-based test items from each of the module-specific tests and a total of 36 questions.

We measured teamwork skills with the Team Skills Scale (Siegler et al., 1998), which assessed students' reported ability to perform different team tasks (e.g. "develop an interprofessional care plan," "intervene effectively to improve team functioning"). The scale included 15 items measured on a five-point Likert-type scale ranging from 1 (*poor*) to 5 (*excellent*), including ability to carry out different team tasks. We computed the mean scale scores before and after the interventions were delivered and compared the pre and post scores to determine changes in self-reported team skills. The mean scale's score could range from one to five and was computed by adding the values students chose for each of the 15 items of the scale, then dividing the total scale score by 15. The Cronbach's alpha for the scale for 2011 Cohort was 0.73 and for 2012 Cohort was 0.94.

We measured attitudes with the Attitudes Toward Health Care Teams Scale (Siegler et al., 1998). The scale comprised three subscales, which were determined in previous research through factor analysis (Leipzig et al., 2002): Team Value (11 items), Team Efficiency (five items), and Shared Leadership (five items). The attitudes toward Team Value measured "attitudes about whether team care improves patient outcomes through consensus on the needs and priorities of the patient" (Leipzig et al., 2002). The attitudes toward Team Efficiency subscale measured "attitudes about whether teams waste time through inefficiencies such as use of discipline-specific jargon" (Leipzig et al., 2002). Lastly, the attitudes about Shared Leadership, measured "values of shared leadership and equality among team members" (Leipzig et al., 2002). All three subscales had items with response options ranging on a six-point Likert-type scale from 1 = strongly disagree to 6 = strongly agree. We computed the mean subscale scores before and after the interventions were delivered and compared the pre and post scores to determine self-reported changes in three attitudinal domains. The mean subscales' scores

could range from one to six and were computed by adding the values the students chose for each of the items of the subscale, then dividing the total subscale score by the total number of items in each subscale. The Cronbach's alpha for the subscales were: Team Value subscale for 2011 Cohort was 0.87 and for 2012 Cohort 0.82; Team Efficiency subscale for 2011 Cohort 0.83 and for 2012 Cohort 0.69; and Shared Leadership subscale for 2011 Cohort 0.60 and for 2012 Cohort 0.63.

Statistical analyses

All data were examined using descriptive statistics. To examine changes in knowledge, skills, and attitudes over time, within each intervention cohort (blended-learning intervention and virtual learning intervention) and within each student group (medical students and nursing students), we used one-sample t-test (Tabachnik & Fidell, 2007). To compare difference in change from 0 months to 12 months between two intervention cohorts in knowledge, skills, and attitudes, we also used independent samples t-test (Tabachnik & Fidell, 2007). Significance level was set at $p < 0.05$ for all tests. We used SPSS Inc. Version 22.0 (Armonk, NY) for all analyses.

Ethical considerations

The study was approved by the institutional review board at the institution, where the study was conducted.

Results

As indicated in Tables I–IV, medical and nursing students from both intervention cohorts made improvements in most domains of the interprofessional teamwork skills, attitudes, and knowledge.

Medical students intervention comparisons

As shown in Table I, both medical student intervention cohorts reported a significant increase in team skills from baseline to 12 months. These gains were not significantly different across the two cohorts. For shared leadership, no significant improvements were reported for the blended-learning cohort, compared to significant improvements in the virtual cohort. This difference across cohorts was significant. For team efficiency, neither of the cohorts showed significant improvements. For team value, the blended-learning cohort reported significant improvements in the mean team value score, while no significant improvements were noted for the virtual cohort. This across-cohort difference was significant.

From Table II, a significant increase in knowledge at 12 months was found for all five domains for the blended-learning cohort. For the virtual cohort, significant increase at 12 months was found for team members' roles and responsibilities and for teams and teamwork, but not for communication and conflict resolution, bioinformatics, or interprofessional care planning. The gains in the two cohorts were not significantly different at 12 months.

Nursing students cohort comparisons

As shown in Table III, students in the blended-learning cohort experienced significant improvements in team skills and all three attitudinal domains. Students in the virtual cohort showed significant improvements in team skills and shared leadership but not team efficiency or team value. None of the gains were significantly different across cohorts.

From Table IV, the blended-learning cohort showed significant improvements for teams and teamwork and bioinformatics and decline in the other three knowledge domains, while the virtual

Table I. Comparison of teamwork skills and attitudes between blended intervention cohort ($N=101$) and virtual intervention cohort ($N=141$) for medical students.

Measure	Intervention cohort	Time 0 M (SD)	Time 2 (at 12 months) M (SD)	p Value ^a	p Value ^b
Team skills	Blended	3.56 (0.58)	3.76 (0.80)	0.019	0.065
	Virtual	3.62 (0.63)	4.12 (0.52)	0.010	
Shared leadership	Blended	3.08 (0.80)	2.92 (0.73)	0.129	0.005
	Virtual	2.87 (0.69)	3.06 (0.74)	0.001	
Team efficiency	Blended	4.38 (0.85)	4.47 (0.78)	0.101	0.557
	Virtual	4.42 (0.72)	4.77 (0.78)	0.564	
Team value	Blended	4.83 (0.61)	4.90 (0.69)	0.011	0.006
	Virtual	4.90 (0.54)	5.35 (0.53)	0.785	

^a p Value for the change in score from Time 0 to Time 2.

^b p Value for the difference in change score from Time 0 to Time 2 between blended and virtual cohorts.

Table II. Comparison of teamwork knowledge between blended intervention cohort ($N=101$) and virtual intervention cohort ($N=141$) for medical students.

Measure	Intervention cohort	Time 0 M (SD)	Time 2 (at 12 months) M (SD)	p Value ^a	p Value ^b
Team members' roles and responsibilities	Blended	4.29 (2.06)	5.77 (1.38)	0.001	0.613
	Virtual	4.26 (2.06)	6.01 (1.46)	0.001	
Teams and teamwork	Blended	5.29 (1.72)	6.67 (1.46)	0.001	0.296
	Virtual	5.16 (2.00)	6.80 (1.23)	0.001	
Communication and conflict resolution	Blended	5.51 (1.93)	6.24 (1.88)	0.002	0.816
	Virtual	5.66 (1.79)	6.42 (1.62)	0.563	
Bioinformatics	Blended	1.99 (1.79)	4.19 (1.27)	0.001	0.868
	Virtual	2.37 (1.78)	4.56 (1.25)	0.953	
Inter-professional care planning	Blended	2.54 (1.74)	3.81 (1.31)	0.001	0.166
	Virtual	2.48 (1.74)	4.01 (1.50)	0.765	

^a p Value for the change in score from Time 0 to Time 2.

^b p Value for the difference in change score from Time 0 to Time 2 between blended and virtual cohorts.

Table III. Comparison of teamwork skills and attitudes between blended intervention cohort ($N=119$) and virtual intervention cohort ($N=399$) for nursing students.

Measure	Intervention cohort	Time 0 M (SD)	Time 2 (at 12 months) M (SD)	p Value ^a	p Value ^b
Team skills	Blended	3.75 (0.80)	4.03 (0.75)	0.001	0.843
	Virtual	3.72 (0.73)	3.97 (0.63)	0.001	
Leadership	Blended	3.51 (0.84)	3.97 (0.92)	0.011	0.090
	Virtual	3.64 (0.84)	3.89 (0.90)	0.001	
Team efficiency	Blended	4.45 (0.98)	4.59 (1.08)	0.005	0.458
	Virtual	4.48 (0.78)	4.45 (1.00)	0.561	
Team value	Blended	5.06 (0.68)	5.02 (0.96)	0.001	0.525
	Virtual	4.96 (0.63)	5.01 (0.75)	0.204	

^a p Value for the change in score from Time 0 to Time 2.

^b p Value for the difference in change score from Time 0 to Time 2 between blended and virtual cohorts.

Table IV. Comparison of teamwork knowledge between blended intervention cohort ($N=119$) and virtual intervention cohort ($N=399$) for nursing students.

Measure	Intervention cohort	Time 0 M (SD)	Time 2 (at 12 months) M (SD)	p Value ^a	p Value ^b
Team members' roles and responsibilities	Blended	6.38 (1.23)	6.31 (1.66)	0.001	0.006
	Virtual	6.34 (1.49)	6.83 (1.20)	0.001	
Teams and teamwork	Blended	5.47 (1.62)	5.88 (2.06)	0.001	0.008
	Virtual	5.69 (1.40)	6.70 (1.37)	0.001	
Communication and conflict resolution	Blended	5.40 (1.82)	5.38 (2.17)	0.001	0.035
	Virtual	6.01 (1.62)	6.51 (1.65)	0.001	
Bioinformatics	Blended	2.55 (1.43)	3.29 (1.44)	0.001	0.118
	Virtual	2.61 (1.54)	3.77 (1.36)	0.001	
Inter-professional care planning	Blended	3.74 (1.45)	3.57 (1.84)	0.001	0.004
	Virtual	3.62 (1.48)	4.30 (1.35)	0.001	

^a p Value for the change in score from Time 0 to Time 2.

^b p Value for the difference in change score from Time 0 to Time 2 between blended and virtual cohorts.

cohort improved across all five team knowledge domains. The gains for the virtual learning cohort were significantly higher compared to the blended-learning cohort for four out of five domains including: team members' roles and responsibilities, teams and team work, communication and conflict resolution, and interprofessional care planning. The gains for the bioinformatics domain were not significantly different across the cohorts.

Discussion

This was one of the first studies to evaluate the effectiveness of a unique virtual learning approach in comparison with a blended-learning approach for IPE. Given the advantages of the virtual learning over a blended-learning approach for scalability, sustainability, faculty training and workload, and student scheduling, we wanted to examine if any unfavorable differences existed in learning outcomes between two learning approaches for an IPE program (Djukic et al., 2012). We hypothesized that there would be no differences between the two learning approaches for IPE knowledge, skills, and attitudes between two intervention cohorts. The support for our hypothesis varied depending on the type of learner (medical versus nursing students) and the type of outcome (knowledge, skills, or attitudes).

For medical students our hypothesis was supported for all five knowledge domains, team skills, and one out of three attitudinal domains – team efficiency. For shared leadership, the virtual medical student cohort improved more than the blended-learning cohort, while for team value, the blended-learning cohort improved more. Therefore, we conclude that for our program, medical students who participated in the virtual IPE intervention reported similar changes in their team skills and attitudes as the students from the blended-learning cohort. The exception is noted in attitudes for team value that appear to be learned more effectively with a blended-learning approach.

For nursing students, the hypothesis was supported for team skills, all three attitudinal domains, and for one out of five knowledge domains—bioinformatics. The virtual nursing cohort performed significantly better than the blended-learning cohort for four out of five knowledge domains. Therefore, for nursing students we conclude that the virtual IPE learning approach had no disadvantages over a blended-learning approach for our program.

Our findings are largely congruent with existing evidence on the effectiveness of e-learning (Feng et al., 2013; George et al., 2014; U.S. Department of Education, 2010) and virtual patients (Cook et al., 2010) for a variety of clinical topics. We add to this evidence by demonstrating that the virtual learning approach is not less effective than the blended-learning approach for IPE. Further, this study highlights an interesting phenomenon that authenticity and relevance of the educational topic may be more compelling to the learner than fidelity. In our study, faculty crafted virtual teammates to represent optimal interprofessional partners who provided helpful and positive clinical notes and comments. These virtual mimics of actual teammates had no apparent detrimental effects on student outcomes and provided all benefits of a scalable and truly asynchronous e-learning intervention.

An additional benefit of our program is that all components of the virtual IPE intervention are available for implementation by other schools at no cost on our website. For each successfully completed IPE module, a student receives a certificate of completion, which provides a confirmation that the student met the learning outcomes for the module. These certificates can become part of professional portfolios or submitted to faculty as a proof that a course assignment was completed. The virtual IPE program might be of particular

benefit to medical and nursing schools that do not have a medical or a nursing school partner on the same campus or even in the same geographic area.

Next, in line with the wider IPE agenda (IOM, 2013), researchers should use prospective longitudinal cohort studies to follow students over time and determine impact of IPE on their team behaviors and patient outcomes. Also, exploring patients' IPE perspectives is needed to meet the demand for patient-centered care, an integral component of the nation's triple aim for health. Our team is well positioned to conduct longitudinal evaluation of the IPE program with medical and nursing students who continue to practice at our academic medical center and engage patients from local communities in building the next version of this IPE program. The longitudinal approach would also help us explain what personal and contextual factors facilitate or impede translation of gains in knowledge, skills, and attitudes from IPE interventions delivered in schools into actual changes in behavior by providers at the point of care. While we expect, based on information deficit models that "information generates knowledge, which shapes attitudes, which lead to behaviour" (Kolmuss & Agyeman, 2002 as cited in Darnton, 2008, p. 10), more comprehensive models of behavior change point to a complex interplay of personal (e.g. emotions, self-regulation), institutional (policies and work processes that reward interprofessional collaboration), and societal (e.g. accreditation and financial reimbursement incentives for interprofessional collaboration) influences in behavior change (Darnton, 2008). Further, based on the literature specific to interprofessional education and practice (IOM, 2013), examples of contextual factors that should be studied in longitudinal designs to explain facilitators and barriers of translating knowledge gain into practice change include the presence of culture, positive role models, and incentives for interprofessional teamwork in practice settings.

Additionally, our decision to limit the study to medical and nursing students was driven by the funder's priority at the time to focus on these two professions and by having senior leadership buy-in to make dramatic changes in nursing and medicine curricula with intent to set the stage for broader collaborations. Since our study was originally funded, the funder has broadened the interprofessional mission to be all inclusive and our school has initiated IPE projects which include dental students, for example. Therefore, we plan to also broaden the interprofessional focus of this IPE program in its future iterations.

Lastly, although we did not formally compare the implementation costs and resources of the two interventions, we quickly recognized that the blended-learning approach would not be sustainable or scalable in our case. For example, implementing the 4-hour in-person faculty-facilitated seminar and small-group learning session (which was a component of the blended-learning intervention) requires finding a space that can accommodate 400 students and faculty facilitators as well as rooms for break-out sessions, ordering and paying for food, beverages, and keynote speaker as well as transportation for nursing students to come to the medical school campus, since our campuses are not co-located. Additionally, the blended-learning intervention required training for faculty facilitators who donated their time for both training and actual facilitation of small-group learning sessions. We could not rely on faculty volunteers as a long-term solution for staffing our program. Also, finding a time when all students and faculty could meet in-person was a significant challenge due to vastly different schedules for our medical and nursing students and faculty. The fundamental differences in academic schedules affected several aspects of our project. Specifically, the nursing school accepts students in both the fall and the spring each year. The nursing students who entered in the fall, at the same time as medical students, were easily and effectively paired to complete

the on-line modules together. However, the nursing students who started in the spring had no medical student cohort with which to pair, which prompted our development of the virtual IPE approach. The traditionally recognized challenges of IPE (Abu-Rish et al., 2012), including the scale of learners, the resources needed to coordinate curricula, and the challenges of bringing groups together, were all barriers we saw in our local efforts. The virtual IPE approach we took enabled us to deliver a curriculum in a flexible and scalable manner that would have otherwise failed if we used a traditional/in person only approach. The online learning modules require relatively little faculty oversight and have enabled us to not only continue, but to expand their use after the grant period, with close to 2500 students completing the on-line program components to date. This is rare among grant-funded educational interventions.

This study has several limitations. Since this was a global and mandatory part of the curriculum, no contemporaneous control group was available to help determine the contribution of other environmental factors, other than the curriculum, that could account for the fact that the virtual intervention cohort improved more on some measures than did the blended-learning cohort while improving less on others. However, we are not aware of any major changes in the overall medical and nursing school curricula between the two cohorts. The inconsistencies we noted in terms of how much the outcomes we measured improved between the students who received the blended-learning versus the virtual learning intervention are likely explained by student and environmental factors that we did not measure and that we could not control for with our study design such as gender, personality traits, personal learning style, previous life experience, or clinical experiences that could have affected students' knowledge, skills, and attitudes about interprofessional teamwork either directly or through the interaction with the different learning approaches. It is already apparent that professional grounding (nursing versus medicine) is one likely contributing factor to differential performance of the two interventions based on differences we noted between medical and nursing students within the same intervention cohort. Further, given the study design limitations, we could not answer the question of how the learning intervention itself might have influenced learning outcomes. We believe that a qualitative approach could help uncover the processes by which the learning method might have influenced the outcomes we studied. We can speculate that, for example, the medical students who participated in the virtual learning intervention scored higher on the shared leadership attitudinal scale than the students who participated in the blended-learning intervention because medical students might be more willing to abdicate or share power with nursing students in a virtual world instead of face-to-face interactions. In terms of measurement limitations, this study used several measures that, although widely validated in the past, were self-reported and could include bias and a social-desirability effect in the responses. Further, some of our measures of team skills and attitudes toward health care teams had Cronbach's alpha <0.7, which is less than what is generally considered adequate internal consistency reliability for measures that are not new (Nunnally & Bernstein, 1994). Lower than desired reliabilities for these measures could have resulted in attenuation of the effect of our interventions on these measures. Lastly, the students were recruited from one medical and nursing school in NYC, and therefore the findings should be generalized with caution to general medical and nursing student populations.

Concluding comments

The mandate for greater amounts of IPE across health professions' education is clear. Schools have been seeking creative solutions to

overcome the pragmatic and organizational barriers to IPE becoming more of a routine component of curricula. We demonstrated that a virtual IPE learning approach has no disadvantages over a blended-learning IPE approach, except for improving medical students' attitudes around team value. If solutions like virtual IPE education can improve teamwork knowledge, skills, and attitudes, it can potentially be a mechanism to increase the presence of this topic across multiple schools in a fashion that is less costly, can scale to reach many students, and requires far fewer in-person faculty facilitation and resources. Online learning and virtual collaboration may not be enough to establish the whole breadth of IPE competencies, but represents an effective and efficient first step towards building IPE competencies in nursing and medical schools for novice learners.

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Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the writing and content of this article.

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