Student-Led Curricular Approaches in Medical Education: The Value-Added Effects of a Virtual Fundamentals of COVID-19 Course

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Abstract

Background As the field of education was adapting to virtual learning during the COVID-19 pandemic, a need quickly emerged for a course to prepare medical students for future clinical practice. This call to action was answered by creating an innovative Fundamentals of COVID-19 course at the Indiana University School of Medicine (IUSM). As a group of medical student leaders at IUSM, we developed this online course in order to support our fellow students and the community. The course was implemented in May 2020 and enrolled a total of 724 third- and fourth-year medical students. Subsequently, we carried out a research study about this student-led curricular approach and its implications for medical education.

Methods The study examined the value-added educational effects of completing the Fundamentals of COVID-19 course. In order to examine these effects, the study asked enrolled students to complete both a pre- and post-course self-assessment survey. Students were asked an identical set of questions on each survey about their knowledge (7), skills (5), and abilities (5) (KSA) regarding COVID-19. Composite scores were created for each KSA learning domain. Responses were provided using a five-point Likert scale ranging from 1 = *strongly disagree* to 5 = *strongly agree*.

Results Out of the 724 students enrolled, 645 students completed both the pre- and post-course assessment surveys. Findings show that there were both meaningful and statistically significant differences in students' responses to the pre- and post-course surveys. Results show 1.) a significant mean increase in the knowledge composite score of 1.01, 95% CI [0.95, 1.06], $t(644) = 36.4$, $p < .001$, $d = 1.43$; 2.) a significant mean increase in the skills composite score of .55, 95% CI [0.50, 0.60], $t(644) = 20.70$, $p < .001$, $d = 0.81$. and 3.) a significant mean increase of the abilities composite score of 1.02, 95% CI [.97, 1.07], $t(644) = 36.56$, $p < .001$, $d = 1.44$.

Conclusions These findings demonstrate that the student-developed, online Fundamentals of COVID-19 course resulted in value-added educational effects. Overall, this study provides evidence to support virtually delivered, student-led curricular approaches in medical education.

Introduction

In the spring of 2020, students at the Indiana University School of Medicine (IUSM) directly responded to an immediate need for new curriculum related to COVID-19. During this time, undergraduate medical students' direct patient care responsibilities were temporarily suspended due to the pandemic. "Answering the Call to Action: COVID-19 Curriculum Design by Students for Students" described how as a small group of student leaders we came together to develop a course that would prepare students for delayed clerkship experiences and COVID-19[1].

We accomplished this goal by completing a student-led curriculum design class. The class, Leadership in Medical Education Elective During the COVID-19 Pandemic, was the first of its kind at IUSM. Through completing this class, we developed a virtual Fundamentals of COVID-19 course that all third- and fourth-

year IUSM students enrolled in during May of 2020. With the help of IUSM faculty and educational experts, we conducted a quasi-experimental research study in order to evaluate the student learning that occurred as a result of completing the Fundamentals of COVID-19 course. Findings from the research study demonstrate that the virtual course resulted in substantial value-added educational effects. Subsequently, a brief overview of research relevant to understanding student-led curriculum and medical education during COVID-19 is provided, followed by a detailed discussion of the research study, significant findings, and implications for the future of medical student education.

Background and Literature Review

Medical Education during COVID-19

It is clear that the COVID-19 pandemic continues to rapidly change medical students' classroom learning and clinical education. Hall et al.[2] are correct to point out, "The COVID-19 global pandemic is challenging healthcare systems in unprecedented ways, affecting not only the delivery of care, but also our delivery of medical education." Scholarship describes solutions to these challenges are necessary during this critical time[2-5]. Rose[4] puts forth, "While in the midst of this COVID-19 crisis, it is crucial that the academic educational community learns from the experiences and prioritizes a forward thinking and scholarly approach…" Our study directly responds to these calls for action by examining the value-added educational effects of a virtual Fundamentals of COVID-19 course. This innovative learning intervention was led by students and presents an effective way to respond to the challenges of the COVID-19 pandemic on medical student education.

Course Development

The Fundamentals of COVID-19 course was intentionally designed to teach medical students the knowledge, skills, and abilities, (KSA) necessary to learn within and respond to the pandemic as they prepare for clerkships. The two-week virtual course intentionally adopted the KSA framework because it is often used in federal employment applications such as those used by the Centers for Disease Control. Additionally, Horst and Pendegrast[6] present a model similar to the KSA framework as part of their taxonomy of effective assessment practice in education and explain that the development of course learning objectives (CLOs) should start the curricular development process. The Fundamentals of COVID-19 course adopted the backwards design approach recommended by Horst and Pendegrast[6] and first focused on developing CLOs. IUSM faculty, educational experts, and student leaders developed a total of 20 specific CLOs that were mapped to our Institutional Competencies (Appendix 1) and were evaluated through knowledge (7), skills (5), and abilities (5) domains. For example, major goals of the COVID-19 course included students becoming knowledgeable about the virology and immunology of COVID-19, and students gaining the ability to identify at-risk populations for COVID-19. Altogether, these types of student learning outcomes guided the overall development of the virtual Fundamentals of COVID-19 course.

Recent studies have shown that the creation of transition-to-clerkship courses improves student comfort upon returning to clerkships[7]. Similar to many transition-to-clerkship courses, the Fundamentals of COVID-19 course was created to improve students' readiness to re-enter the clerkship phase of their medical training. The student-led curriculum design, virtual implementation, and the overall scale make the Fundamentals of COVID-19 course at IUSM a compelling educational intervention for academic research.

Student-led Curricular Development

The argument for student-led curriculum has been discussed numerous times over the years but there has been limited implementation of this curricular approach at medical education institutions, including IUSM[8]. Medical school graduates are expected to teach upon entering residency, but they are often not given the appropriate training or opportunities to practice this vital task. At a basic level, a student-led curriculum provides the tools to help medical students become better teachers[9]. Research suggests that exposure to teaching principles, techniques, and skills should begin in medical school and continued through residency and clinical practice[10]. Furthermore, recent literature highlights the advantages of the student perspective as students have a "heightened sense" of curricular gaps and thus are able to "capture different sets of needs...via a student-centered approach.[11]" Students at the Johns Hopkins University School of Medicine have a Student Curriculum Review Team (SCRT) that provides a pathway for student-feedback to play an integral role in curricular development[12]. The SCRT contends that, "As consumers of education, students have the right and responsibility to be involved in curricular reform and communicate their ideas freely.[12]" Taken together, these perspectives demonstrate the benefits of student-led curriculum and its increasing importance to health sciences education.

The student-led development of the Fundamentals of COVID-19 course at IUSM was largely shaped by the need to deliver new curriculum about the pandemic to third- and fourth year students in a completely virtual format. Online curriculum has become increasingly popular due to increased demands for faculty productivity, resulting in decreased time for traditional teaching methods, especially in the face of a pandemic[13]. Educators are now more than ever leveraging the use of technology in undergraduate and graduate medical education[14]. For example, Anupan et al.[3] describe the use of rapid design thinking as a way to overcome COVID-19 challenges in medical education. Within this framework, "the goal is to develop accelerated solutions that are also human-centered or enhance the user experience"; and leveraging digital technology is described as the primary way to achieve these goals[3].

Subsequently, the research that we present is important for two main reasons. First, it provides evidence that student learning occurred as a result of the Fundamentals of COVID-19 course. This evidence is critical for further developing medical education during the pandemic. The research also suggests that having students intricately involved in the development of curriculum is a benefit to medical education beyond emergencies such as the current pandemic. Prior to this study, student-led curriculum about COVID-19 had not been adequately investigated in the medical education literature.

Methods

Research Framework

A quasi-experimental research design was implemented to understand student learning in the Fundamentals of COVID-19 course at IUSM. The 724 students who enrolled in the class during the Spring of 2020 were asked to complete both a pre- and post-course assessment survey. This type of research design, characterized by the use of pre- and post-course surveys, has been used effectively in medical education and general higher education to assess the success of new learning interventions[15,16]. Additionally, Pohlmann and Boggs's[17] foundational work on the validity of self-reported measures of academic growth support this type of research framework. The surveys were developed to measure students' KSA, as they relate to COVID-19. The two surveys are directly connected to the CLOs and contain an identical set of KSA self-assessment question items. We examined the matched dataset of student ratings to identify statistically significant differences in students' self-assessment ratings prior to and after completing the course. The self-assessments intentionally asked the students to rate their confidence with completing specifics skills and abilities because the students were unable to practice their clinical skills in an in-person teaching environment due to the pandemic.

Ethical Considerations

Approval for this study was obtained from the Indiana University, Institutional Review Board (IRB). The protocol number is 2004320338. This approval ensured ethical safeguards and confirmed that the study procedures were carried out under all appropriate guidelines, regulations, and policies. The study participants were informed that their survey responses would be used for both research and institutional improvement purposes. Informed consent was obtained from all study participants. The IRB approval contained exempt status for the study so that participants' confidentiality would be not be placed at risk by collecting written documentation. The study adhered to all ethical standards of human subjects research and was performed in accordance with the Declaration of Helsinki.

Questions and Likert Scale

The students completed the two assessments by rating their level of agreement with 17 statements that measured their KSAs as they relate to COVID-19. Students also responded to additional questions on the post course survey which asked about topics that could only be evaluated by the students after they completed the course, such as the overall success of the course and the effectiveness of the virtual delivery of course content. The students rated their level of agreement with all the question items using a five-point Likert scale: 1 = *Strongly Disagree*; 2 = *Disagree*; 3 = *Neutral*; 4 = *Agree*; 5 = *Strongly Agree*.

Ordinal and Interval Data

The ordinal data collected were converted to numbers (e.g., 3 = Neutral) and treated as interval data for the purpose of statistical analysis.

Composite Scores

Composite scores were created by averaging the student ratings across all questions of a specific learning domain. Averages were calculated for both the pre- and post- course surveys. This resulted in both a pre- and post- composite score for each KSA learning domain. Composite scores are often used in education and can be seen in, for example, grade point averages (GPA). The use of composite scores provided an effective way to consider the change in students' self-assessment ratings over time.

Paired-samples t-tests and Assumptions

Paired-samples t-tests were used to determine if there were statistically significant mean differences between students' self-assessment scores on the pre-course survey compared to the post-course survey for each learning domain. The within-subject parametric tests compared the two matched groups of the independent variable (IV), pre- and post-course survey responses, on one dependent variable (DV). The DV changed for each test to include a specific composite score – knowledge, skills, or abilities. Paired-samples t-tests were also conducted on individual question items in order to learn more about student learning of COVID-19.

The paired-samples t-tests met the required statistical assumptions. For each test, there were no significant outliers in the differences between the matched pre- and post- course survey groups. Additionally, for each test, the assumption of normality was not violated, as assessed by visual inspection of Normal Q-Q plots. Finally, a Bonferroni correction was made on the preset probability (*p*) values of the paired-samples t-tests.[18-19] The correction was made because conducting multiple statistical tests exponentially increases the risk of Type 1 error. The preset probability value (*p*) of the statistical tests in this study was .05. After the Bonferroni correction was applied (.05 / 17 question specific t-tests) the preset *p* value was adjusted to .003 and then used throughout the study.

Results

Respondent Characteristics

Of the 724 students enrolled in the course, 678 (93.6%) completed the pre-course survey, and 681 (94.1%) students completed the post-course survey. The matched dataset used in analysis only included the 645 (89.1%) students who completed the self-assessment on both the pre- and post- course surveys. The matched data set includes 48.4% (312) third-year and 51.6% (333) fourth-year medical students. Demographics of students in the dataset are similar to the demographic characteristics of IUSM students overall: 45.9% (296) of respondents self-identified as female, 51% (329) as male, 0.3% (2) as nonbinary, and 2.8% (18) indicated that they prefer not to answer questions about gender identity. Additionally, 25.3% (163) respondents self-identified as minority students, and 67.1% (433) as white students. Lastly, 7.6% (49) of students chose not to answer demographic questions about race and ethnicity.

Findings

Overall, results show higher student ratings on the post-course survey compared to the pre-course survey across all KSA learning domains. For example, composite scores means for each KSA learning domain show an increase in students' self-assessment ratings after the course was completed compared to the matched pre-course survey results (Figure 1). These results are both statistically significant (p <.001) and substantial as measured by Cohen's d. Subsequently, details associated with these results are presented. Students' learning gains in knowledge associated with COVID-19 are presented first. This is followed by findings associated with students' learning gains in skills and abilities associated with COVID-19.

Knowledge

Results from a paired-samples t-test show students responded with higher self-assessment ratings about their knowledge of COVID-19 on the post-course survey (M = 4.04, SD = 0.53) compared to the pre-course survey (M = 3.03, SD = 0.62) with a significant mean increase of the knowledge composite score of 1.01, 95% CI [0.95, 1.06], $t(644) = 36.44$, p <.001, $d = 1.43$ (Figure 2).

It is notable that the effect size, as measured by Cohen's d, is large (1.43) indicating that students' scores on the pre- and post-course self-assessments are substantially different. Individual paired-samples t-test conducted on matched responses for the seven knowledge question items show statistically significant mean increases ranging from 0.65 to 1.36 as well as notable effect sizes (Table 1).

Table 1: Students Pre- and Post-Survey Responses on COVID-19 Knowledge Questions

	COVID-19 Knowledge	Pre-Survey (N = 645)		Post-Survey (N = 645)		Mean Difference	Effect Size
	Students' Self-Assessment Ratings	M	SD	M	SD	(+/-)	*d*
K1	I am knowledgeable about virology and immunology as they relate to COVID-19.	3.08	0.81	4.02	0.61	0.94***	1.08
K2	I am knowledgeable about the pathophysiology of COVID-19.	2.88	0.82	3.98	0.63	1.10***	1.20
K3	I am knowledgeable about the impact of population health in the context of a pandemic, and in particular for COVID-19.	3.39	0.83	4.18	0.63	0.79***	.90
K4	I am knowledgeable about the impact of social determinants of health in the context of a pandemic, and in particular for COVID-19.	3.57	0.87	4.22	0.63	0.65***	.71
K5	I am knowledgeable about the ways individuals and organizations can advocate at the state and national level during epidemics/pandemics.	2.81	0.90	3.96	0.66	1.15***	1.13
K6	I am knowledgeable about the legal aspects that impact COVID-19 patients, providers, and the community during the pandemic.	2.47	0.87	3.83	0.74	1.36***	1.33
K7	I am knowledgeable about the issues surrounding utilization and preservation of finite resources that impact patients, providers, and the community during the pandemic.	3.03	0.87	4.07	0.63	1.04***	1.07
Knowledge Composite Rating Score		3.03	0.62	4.04	0.53	1.01***	1.43

******* $p < .001$

Skills

Students responded with higher self-assessment ratings about their skills related to COVID-19 on the post-course survey (M= 4.14, SD= 0.57) compared to the pre-course survey (M = 3.59, SD = 0.64). This is a significant mean increase of the skills composite score of .55, 95% CI [0.50, 0.60], $t(644) = 20.70$ $p < .001$, $d = 0.81$ (Figure 3).

The effect size, as measured by Cohen's *d* is moderate to large showing that students' scores on the pre- and post-course surveys are notably different. Results from individual paired-samples t-test conducted on matched responses for the five skills question items also show statistically significant differences as well as moderate to large effect sizes (Table 2). Findings related to the skills associated with COVID-19, as well as the other learning domains, are reviewed further in the discussion section.

Table 2: Students Pre- and Post-Survey Responses on COVID-19 Skills Questions

	COVID-19 Skills	Pre-Survey (N = 645)		Post-Survey (N = 645)		Mean Difference	Effect Size
	Students' Self-Assessment Ratings	M	SD	M	SD	(+/-)	*d*
S1	I am confident in my skills to use principles of evidence-based medicine, including biostatistics, to evaluate efficacy of therapeutic interventions for COVID-19 infection.	3.37	0.94	4.05	0.69	0.68***	.72
S2	I am confident in my skills to analyze the management of epidemics and pandemics historically and in modern medicine.	3.14	0.90	4.09	0.67	0.95***	.96
S3	I am confident in my skills to identify a research question.	3.98	0.77	4.26	0.67	0.28***	.36
S4	I am confident in my skills to appraise the quality and credibility of a source and synthesize the information to advance my understanding of pandemic responses.	3.84	0.77	4.14	0.66	0.30***	.36
S5	I am confident in my skills to implement basic strategies for mental health and wellbeing promotion for providers in the face of a healthcare emergency, and understand their importance to overall health.	3.60	0.81	4.15	0.65	0.55***	.61
	Skills Composite Rating Score	3.59	0.64	4.14	0.57	0.55***	.81

******* $p < .001$

Abilities

Students responded with higher self-assessment ratings about their abilities related to COVID-19 on the post-course survey (M= 4.05, SD= 0.53) compared to the pre-course survey (M = 3.03, SD = 0.64). This is a significant mean increase of the abilities composite score of 1.02, 95% CI [.97, 1.07], $t(644) = 36.56$, $p < .001$, $d = 1.44$ (Figure 4).

Similar to the findings associated with the other learning domains, the large effect size also indicates that the differences in students' responses are substantial. Results from individual paired-samples t-test conducted on matched responses for the five abilities question items also show statistically significant differences and large effect sizes (Table 3).

Table 3: Students Pre- and Post-Survey Responses on COVID-19 Abilities Questions

	COVID-19 Abilities	Pre-Survey (N = 645)		Post-Survey (N = 645)		Mean Difference	Effect Size
	Students' Self-Assessment Ratings	M	SD	M	SD	(+/-)	*d*
A1	I am confident in my ability to recognize the clinical presentation of a patient with COVID-19.	3.29	0.85	4.12	0.63	0.83***	.92
A2	I am confident in my ability to outline a treatment course for suspected COVID-19 patients.	2.52	0.89	3.82	0.75	1.30***	1.32
A3	I am confident in my ability to identify at-risk populations for poor outcomes with COVID-19.	3.54	0.83	4.26	0.60	0.72***	.82
A4	I am confident in my ability to describe disaster medicine principles, including the processes and policies by which community and international agencies interact to coordinate a safe and effective disaster/pandemic response.	2.55	0.88	3.94	0.65	1.39***	1.42
A5	I am confident in my ability to identify ways of modifying communication strategies based on the context.	3.26	0.88	4.11	0.62	0.85***	.89
	Abilities Composite Rating Score	3.03	0.64	4.05	0.53	1.02***	1.44

******* $p < .001$

Additional Findings

Student Satisfaction

The students in the sample also provided useful feedback about their satisfaction with the course and the virtual delivery of course content using the same five-point Likert scale that was used to assess the KSA learning domains. Results from the post-course survey regarding virtual delivery showed mean ratings of 4.02 (SD = 0.75) and 3.83 (SD = 0.93) for the following statements, respectively: “The technology generally worked well for this virtual course” and “The content was delivered effectively in a virtual format.” Results from the student surveys regarding overall course effectiveness showed mean ratings of 3.70 (SD = 0.996) and 3.69 (SD = 1.02) for the following statements, respectively: “Overall, this course provided an effective learning experience.” and “The virtual delivery of course content did not detract from the overall effectiveness of this class.” Taken together, these results demonstrate that students were generally satisfied with the Fundamentals of COVID-19 course and that they viewed the technology and virtual format positively. This provides further evidence in support of student-led curriculum design and online instruction in medical student education.

Discussion

Value-added Educational Effects

At its core, the results from this study show that the virtual Fundamentals of COVID-19 course resulted in value-added educational effects. The evidence shows that students were more confident in their knowledge, skills, and abilities (KSA) as they relate to COVID-19 after completing the course than prior to starting it. It is notable that students showed improvement in each KSA learning domain as measured by both composite scores and individual questions. The analyses show these differences are statistically significant and substantial as measured by effect size. The results also show that the students who completed the virtual Fundamentals of COVID-19 course were satisfied with the course. Altogether, these findings demonstrate the virtual Fundamentals of COVID-19 course achieved its CLOs and effectively prepared students for clinical training during the pandemic. The findings also have notable implications for how the student-led aspect of the course may have also contributed to these positive educational outcomes.

It is interesting that students self-reported higher ratings for skills question items, on both the pre- and post-surveys, as shown in Figures 1 and 3. These higher ratings likely reflect that skill development is an integral component of the IUSM curriculum overall. Additionally, the relatively limited difference in skill ratings between the pre- and post- course surveys likely speak to the virtual educational delivery platform, which may present a barrier to skill development vis-à-vis in-person learning. Finally, although the positive changes in student ratings from the pre- to post-course assessments are substantial and statistically significant, we cannot fully attribute a causal link between these changes and the effectiveness of the course.

The virtual Fundamentals of COVID-19 course resulted in positive student learning outcomes. The purpose of the course was not to teach students all information on COVID-19, but rather to equip students with the KSA to adapt to ever-changing data and to critically think about the multidisciplinary coordination needed to manage a global pandemic. Findings from our study show that the student-led Fundamentals of COVID-19 course was successful in achieving this goal. Achieving this goal was especially important as many of the medical students who completed the course are now delivering vaccines that are vital to stopping the pandemic. Student improvement, especially in the knowledge and abilities domains, demonstrate that meaningful student learning occurred as a result of the course. Overall, this study's findings have implications about the efficacy of two specific course aspects: (1) efficacy of student-led curriculum development and (2) efficacy of virtual delivery of course content.

Efficacy of Student-led Curriculum Development

Student-led curricular development offers different perspectives and insight into course design. Although this study does not provide comparative data between student-led vs faculty-led curricular development, the overall student satisfaction and reported increase in learning outcomes provides a compelling institutional example of the success of student-led curricular design. The benefits of student-led curricular

design are similar to those of peer teaching, which has been shown to have a “positive impact on both the peer teacher and the learners[20].” This concept is well supported and described in academic literature as cognitive congruence. Lockespier et al[21] shows that the ability of second year students to anticipate problems that first year students might have in understanding particular concepts was important in creating cognitive congruence. Because peer teachers recently learned the material themselves, they are able to share their own struggles, learning experiences, and ultimately describe the approaches that they used to overcome those challenges[20-22]. We consciously applied these peer teaching and learning principles as we led the student development of the Fundamentals of COVID-19 course at IUSM. This intentional application, combined with the strong assessment results, provide further evidence of the efficacy of student-led curriculum development.

Efficacy of Virtual Delivery of Course Content

Results show students tended to agree with the statement that the virtual delivery of course content was effective in the Fundamentals of COVID-19 course. This is also a notable implication in that it provides evidence to support virtual curriculum as an alternative education platform and as an effective tool for large audiences. The Fundamentals of COVID-19 course clearly demonstrates that intentionally developed CLOs can be achieved through the use of a virtual delivery platform in medical education. Although a virtual course may not be as efficacious as in-person or hands-on learning in, for example, clinical skills development, students in this course reported significant academic improvement across all KSA domains. Education, in particular medical education, will forever be different due to COVID-19. Virtual or online education has not only become a necessary aspect of learning but in many cases has become a preferred choice by educators as it saves critical resources and helps ensure student health[21]. It is expected that the use of online platforms to teach and disseminate medical knowledge, skills, and abilities, will continue well into the future.

Limitations

It is important to consider the inherent limitations associated with the data collected in this study. First, there is an innate risk of studies that use a pre- and post- survey design to collect feedback from participants. There is some speculation that this research framework biases improvement as survey takers will have a social desirability bias and purposefully change their answers to positive. However, Lockspeiser et al[21], contend that students have shown to value learning from peers, as was done in the Fundamentals of COVID-19 course, and that they actually may feel more comfortable in providing more honest appraisals of peer-developed resources. Another limitation of this study is that we measured outcomes according to student perceptions. Future studies should build upon the findings that resulted from this research to further understand medical student learning during COVID-19 with additional direct evidence.

This study also has limitations associated with its research design and data analysis procedures. For example, this study examined student learning at one institution. Additionally, because all third- and

fourth-year medical students were enrolled in the Fundamentals of COVID-19 course there was not a control group. Additionally, students' survey responses were examined as interval data. Sullivan and Artino[24] support examining survey data in this way and conclude that "parametric tests can be used to analyze Likert scale response." This conclusion is also supported by others in the medical education and assessment and evaluation literature.[25-26] Notwithstanding, care should always be taken when examining self-reported survey data. Finally, this study incorporated the use of multiple statistical tests. The Bonferonni correction was applied to help account for the increased likelihood of Type I errors. Still, future studies may benefit from using a more streamlined survey instrument which would help to manage the number of statistical comparisons. Although these limitations need to be considered, the study was based on founded assessment approaches, had a relatively large sample size, and met all necessary assumptions required for statistical analysis.

Conclusion

COVID-19 presented medical educators with the barrier of extended lapses of time in in-person student learning. This new reality is occurring at a time when faculty are also being met with increased clinical duties due to a global pandemic. In this time of change, students were able to provide critical leadership by creating a highly effective virtual Fundamentals of COVID-19 course. The student-led course served medical students by facilitating acquisition of KSA necessary to respond effectively to the pandemic. Future curricular development in medical education should seek to leverage student leadership and the many beneficial contributions that they can effectively make in course development. The Fundamentals of COVID-19 course provides a quintessential example of the ability of students and faculty to come together to create effective student education, fill an educational gap caused by COVID-19, and ultimately answer a *Call To Action*[1].

The findings from this study demonstrate that the student-led virtual Fundamentals of COVID-19 course at IUSM resulted in positive curricular outcomes. Most importantly, students learned knowledge, skills, and abilities necessary to respond to the pandemic. As medical education continues to respond to the needs of the pandemic, we encourage other institutions to use resources about the course that we have made publicly available through the AAMC iCollaborative[27]. Future research and curricular development should continue to examine student-led approaches and virtual instruction. A sustained commitment to these goals ensures ever improving training techniques for future physicians through innovative and evidence-based curriculum.

List Of Abbreviations

IUSM = Indiana University School of Medicine

KSA = Knowledge, Skills, and Abilities

CLO = Course Learning Objective

SCRT = Student Curriculum Review Team

GPA = Grade Point Average

IV = Independent Variable

DV = Dependent Variable

N = Study Size

M = Mean

SD = Standard Deviation

CI = Confidence Interval

Declarations

Ethics approval and Consent to Participate: This study was granted exemption by Indiana University's Institutional Review Board, which ensures ethical safeguards and study procedures were adherent to appropriate guidelines, regulations, and policies. Informed consent was obtained by all study participants. The IRB Protocol number is 2004320338. The study was adherent to all ethical standards of human subjects research in accordance with the Declaration of Helsinki.

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Appendix

Appendix 1. Fundamentals of COVID-19 Modules Mapped to Course Learning Objectives, Institutional Indiana University School of Medicine Competencies.

Institutional Competency	Course Learning Objective	Associated Learning Modules
Medical Knowledge (MK)	1) Explain the principles of virology and immunology as they relate to COVID-19.	Virology and Immunology
	2) Identify the causal agents and the management of epidemics and pandemics, including the process of vaccine development in modern medicine.	History of Epidemics and Pandemics in Modern Medicine
		Principles of Disaster Management
		Laboratory Science
	3) Explain the clinical presentation and the pathophysiology of the COVID-19 pandemic.	Virology and Immunology
		Patient Care/Radiology
		Laboratory Science
	4) Evaluate treatment and disease management options using principles of Evidence-Based Medicine (EBM) to apply the latest data for suspected and confirmed COVID-19 patients.	Patient Care/Radiology
		Evidence-Based Medicine Review of Literature on Disease
	5) Use principles of evidence-based medicine, including biostatistics, to evaluate the efficacy and potential for therapeutic and diagnostic interventions for COVID-19 infection.	Virology and Immunology
		Patient Care/Radiology
		Specialty Considerations during the COVID-19 Pandemic
		Evidence-Based Medicine Review of Literature on Disease
		Laboratory

		Science
	6) Apply the science of epidemiology and analyze the management of epidemics and pandemics historically and in modern medicine.	Epidemiology of Disease
		History of Epidemics and Pandemics in Modern Medicine
		Principles of Disaster Management
Patient Care (PC)	7) Analyze clinical presentation and pathologic findings, determine the disease entity, outline a treatment course for COVID19 patients.	Patient Care/Radiology
	8) Recognize common laboratory, radiologic and clinical presentations of disease of COVID-19 patients.	Patient Care/Radiology
		Laboratory Science
	9) Identify at-risk populations for poor outcomes with COVID-19 and preventative measures for these people.	Epidemiology of Disease
		Specialty Considerations during the COVID-19 Pandemic
Practice-Based Learning and Improvement (PBLI)	10) Engage in self-directed learning by identifying a research question, appraising the quality and credibility of sources to answer the research question, and synthesizing the relevant information to advance the understanding of pandemic responses.	Epidemiology of Disease
Interpersonal and Communication Skills (ICS)	11) Identify ways of modifying strategies for communicating about an evolving healthcare topic based on the context and audience.	Telehealth
		Communication Considerations during COVID-19
	12) Share evolving information about the COVID-19 pandemic accurately through appropriate media.	Telehealth
		Communication Considerations during COVID-19
Systems-Based Practice (SBP)	13) Outline the roles of medical professionals and non-medical professionals in responding during epidemics/pandemics.	Principles of Disaster Management
		Laboratory

	Science
	Ethical Considerations during a Pandemic
	Public Policy during the COVID Pandemic
14) Evaluate the impact of population health and social determinants of health in the context of a pandemic, and in particular for COVID-19.	Epidemiology of Disease
	Patient Care/Radiology
	Specialty Considerations during the COVID-19 Pandemic
15) Identify ways in which individuals and organizations can advocate at the state and national level during epidemics/pandemics.	Principles of Disaster Management
	Ethical Considerations during a Pandemic
	Public Policy during the COVID Pandemic
16) Describe disaster medicine principles, including the processes and policies by which community and international agencies interact to coordinate safe and effective disaster/pandemic response.	Specialty Considerations during the COVID-19 Pandemic
	Principles of Disaster Management
	Appropriate Personal Protective Equipment Protocol
	Public Policy during the

		COVID Pandemic
	17) Describe the utilization and preservation of finite resources during disaster/pandemic responses.	Specialty Considerations during the COVID-19 Pandemic
		Principles of Disaster Management
		Appropriate Personal Protective Equipment Protocol
		Ethical Considerations during a Pandemic
		Public Policy during the COVID Pandemic
Professionalism (P)	18) Outline the traits and behaviors of leaders within the medical field.	Leadership and Teamwork Traits during a Pandemic
	19) Identify basic strategies for mental health and wellbeing promotion for providers in the face of a healthcare emergency and understand their importance to overall health.	Wellness and Self-Care for Healthcare Providers during a Pandemic
	20) Debate the legal, psychosocial, and ethical aspects that impact COVID-19 patients, providers, and the community during the pandemic, in particular the issues surrounding resource utilization.	Specialty Considerations during the COVID-19 Pandemic
		Principles of Disaster Management
		Ethical Considerations during a Pandemic
		Public Policy during the

Figures

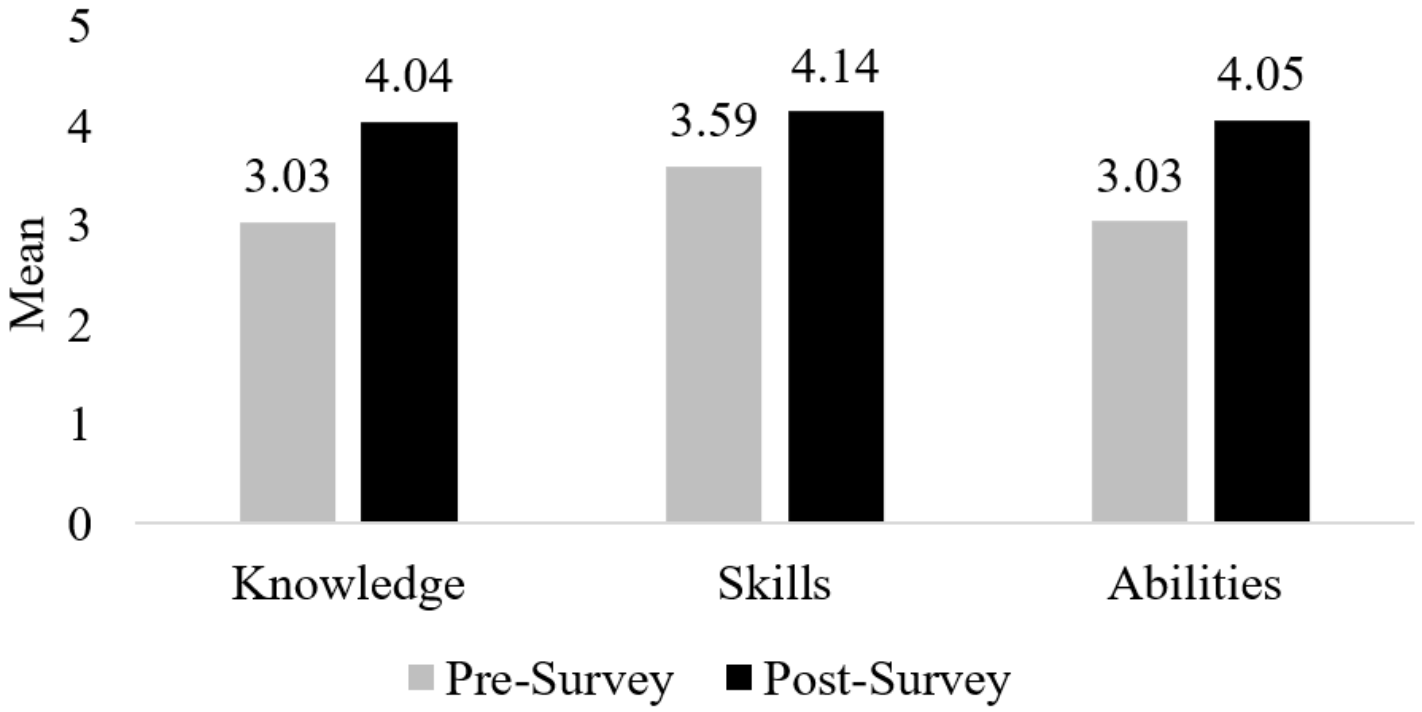

Figure 1

Knowledge, Skills, and Abilities Composite Score Means. Composite score means of student self-reported knowledge, skills, and abilities before and after completing the Fundamentals of COVID-19 course. The mean pre-course (gray) and post-course (black) survey results are shown for each learning domain. Within each learning domain, the post-course survey increase was statistically significant ($p < .001$).

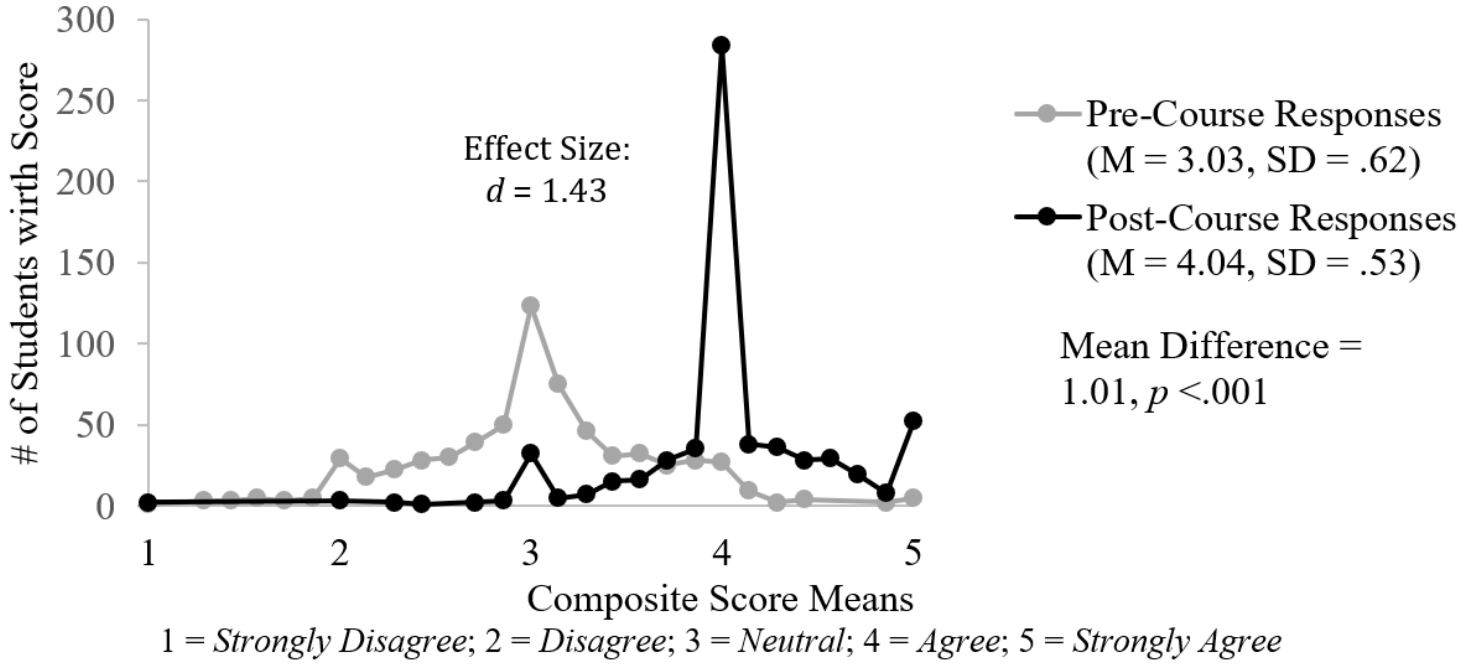

Figure 2

Distribution of Knowledge Composite Score Means Pre- and Post-Course Survey Responses. Distribution of composite score means for students' self-reported knowledge of COVID-19 before and after completing the new- student-led course. The distribution is shown for pre-course (gray) and post-course (black) survey results. The post-course survey aggregate mean increase of 1.01 was both substantial (d = 1.43) and statistically significant (p < .001).

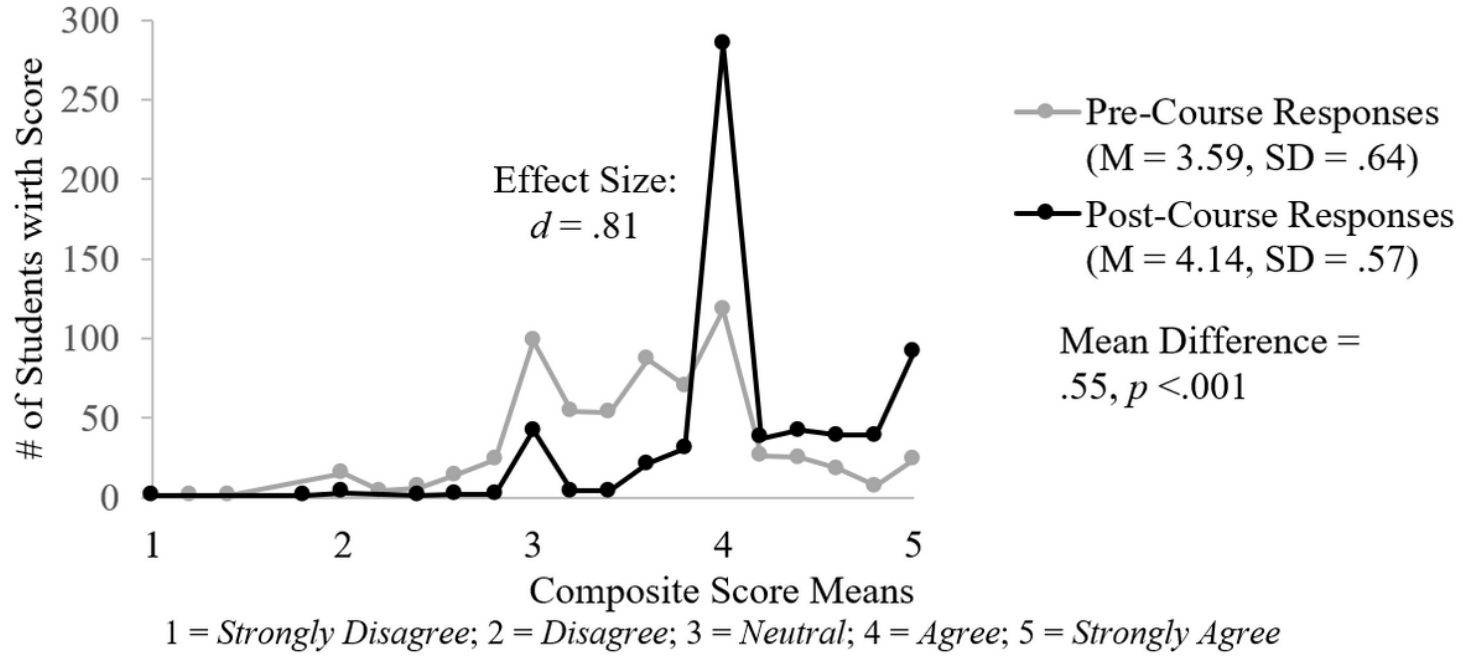

Figure 3

Distribution of Skills Composite Score Means Pre- and Post-Course Survey Responses. Distribution of composite score means for students' self-reported skills related to COVID-19 before and after completing the student-led course. The distribution is shown for pre-course (gray) and post-course (black) survey results. The post-course survey aggregate mean increase of .55 was notable (d = .81) and statistically significant (p < .001).

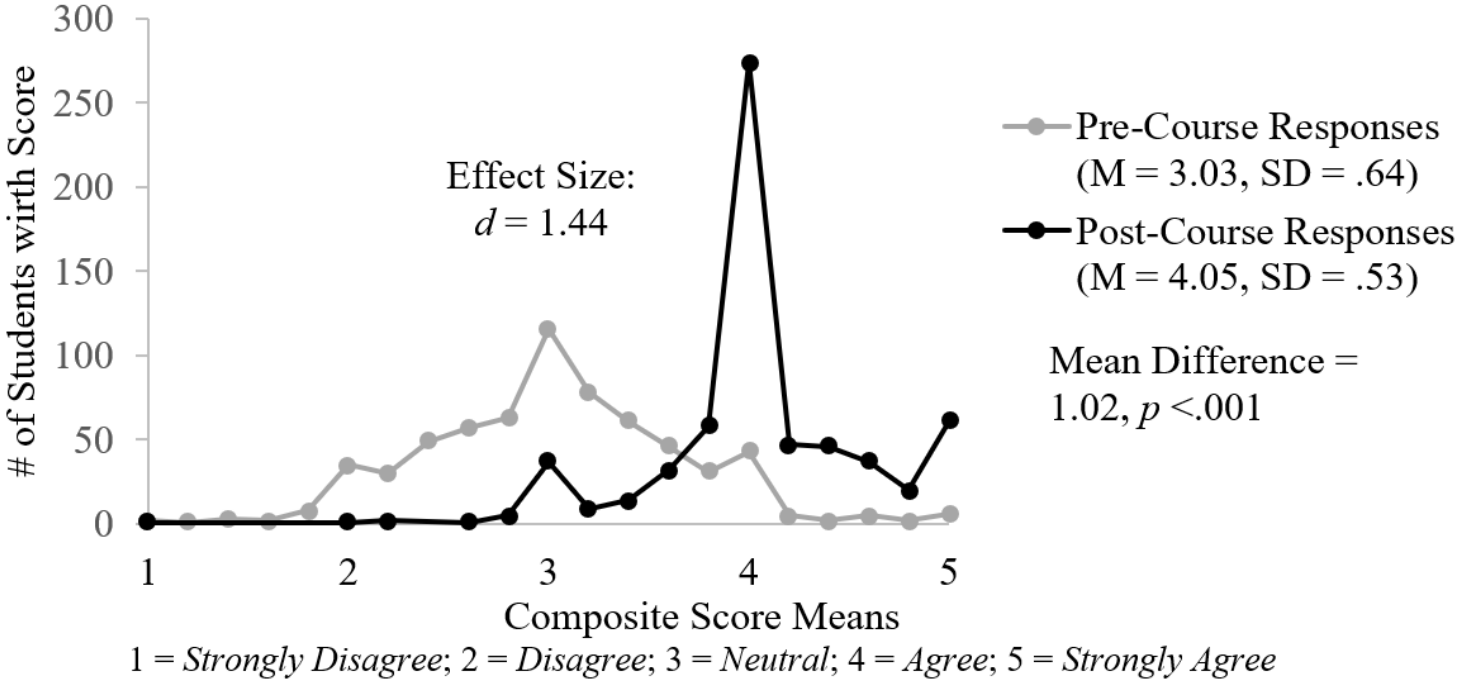

Figure 4

Distribution of Abilities Composite Score Means Pre- and Post-Course Survey Responses. Distribution of composite score means for students' self-reported abilities related to COVID-19 before and after completing the student-led course. The distribution is shown for pre-course (gray) and post-course (black) survey results. The post-course survey aggregate mean increase of 1.02 was both substantial (d = 1.44) and statistically significant (p < .001).