Journal of Science Education and Technology (2022) 31:583–593
https://doi.org/10.1007/s10956-022-09975-y

Epidemiology in Middle School Science Curricula: a COVID-19 Pre–post Intervention

Amani Khalaf H. Alghamdi[1] · **Kholoud S. Al Ghamdi**[2] · **Sun Young Kim**[3]

Accepted: 23 May 2022 / Published online: 11 June 2022

Abstract

It is of great importance that science educators teach COVID-19 and related pandemics to boost students' scientific literacy. A mixed methods research design (pre-post test instrument [$N=86$] and semi-structured interviews [$N=11$]–August 2020 to June 2021) evaluated the ability of an intervention (12 h, three-session, 3-day, online workshop) to augment middle school inservice science teachers' (Eastern Saudi Arabian province) ability to teach about medical terminology and the epidemiology of diseases. Teachers' cognitive gains were measured through evaluating their knowledge, comprehension, and application of workshop content before and after the intervention. Descriptive statistics and inferential *t* tests revealed statistically significant cognitive differences overall ($p<.01$) (posttest mean = 26.26/30, SD 2.83, *t* value 18.51) and along knowledge (posttest mean = 5.72/7), comprehension (mean = 7.50/8), and application (mean = 13.05/15). A high effect size coefficient $n2$ indicated a large effect on cognitive gains. Thematic analysis about participants' subsequent efforts teaching workshop content to students revealed positive and negative experiences. The former included improved student engagement with the curriculum, community connections via project-based learning, and opportunities to teach colleagues about COVID-19. The latter concerned insufficient time, an obligation to teach the current curriculum without adding COVID-19 content, and administrative resistance. Recommendations pertain to augmenting the workshop curriculum and likeminded research initiatives.

Keywords Inservice science teachers · Saudi Arabia · Teaching about COVID-19 and pandemics · Conceptual change · Middle school

Introduction

"Children at any age can get infected with COVID-19" (Kari et al., 2021, p. 543). About one third of Saudi Arabia's population is youth (aged 12–15 years), and roughly 5% have contracted COVID (Alsofayan et al., 2020). This large, socially active teenage cohort must know about what is happening worldwide, especially if this knowledge is important for their health and wellbeing. Also, they often take home what they learn at school. Teaching students about all aspects of life better ensures that knowledge gained from school is spread to their community and the wider population (Almudara, 2019). Teaching them about COVID-19 is timely given the ongoing global pandemic, which manifests in individual infections and community spread.

On a related note, knowledge acquisition starts from early childhood. Educating Saudi youth is associated with internalizing values they can use in their daily lives to contribute to the Kingdom of Saudi Arabia's (KSA) modernized society (Idris et al., 2012). Early education about medical terminology (epidemics and pandemics) and epidemiology further ensures that this information will be consolidated in their long-term memory and turned into habits and lifestyle (Taylor et al., 1994). With the advent of the COVID-19 global pandemic, which has "had an unprecedented impact across the globe"

✉ Amani Khalaf H. Alghamdi
akhalghamdi@iau.edu.sa

Kholoud S. Al Ghamdi
ksaalghamdi@iau.edu.sa

Sun Young Kim
sykim519@chosum.ac.kr

1 College of Education, Curriculum and Pedagogy, Imam Abdulrahman Bin Faisal University, PO Box 1982, Dammam 31441, Kingdom of Saudi Arabia

2 College of Medicine, Higher Studies & Scientific Research, Imam Abdulrahman Bin Faisal University, Dammam, Kingdom of Saudi Arabia

3 Department of Biology Education, College of Education, Chosun University, 61452 Gwangju, South Korea

(MNT Team, 2020, para. 13), teaching this age group about what is going on in the world has become an educational imperative.

The study herein was further predicated on the expectation that history repeats itself, meaning other pandemics are not out of the question despite their infrequency in human history (MNT Team, 2020). The Saudi middle school science curriculum is already rich with information about many important topics including the human body's anatomy and physiology. The Saudi Ministry of Education (MOE) (2021) recently increased the enrichment, application, and exercise aspect of science curricula. With COVID-19 affecting all members of society worldwide (Tanveer et al., 2020), including KSA, the authors judged it imperative that two additional major topics be introduced into the Saudi middle school science curriculum: medical terminology, and the epidemiology of diseases.

To that end, this paper recounts the development and efficacy of a short training course designed to teach Saudi Arabian middle school inservice science teachers these topics. Study outcomes will (a) shed light on the importance of infusing science curricula with concepts preparing students to face the real, pandemic-shaped world; (b) help MOE decision makers design new science curricula; and (c) discern Saudi science teachers' readiness and willingness to gain new knowledge about pandemics and epidemiology and efficiently apply it using effective teaching methods.

Literature Review

After discussing the importance of teaching medical terminology and the epidemiology of diseases, the literature reviewed concerns pedagogical knowledge, conceptual change strategies, and educators' role relative to ensuring students' health knowledge.

Medical Terminology

Medical terminology as a scientific concept is important to the youth cohort because news outlets, including social media, bombarded them with medical terms about the coronavirus, its origins, and how it is contracted and transmitted relative to the workings of the human body. Many of these unknown medical terms trigged fear and anxiety among people including literate and illiterate (scientific and otherwise) community members. These strong emotions immensely affected their mental health and wellbeing (Sayed et al., 2021; Zakout et al., 2020). The authors reasoned that middle school science students should at least be enlightened about these terms and how they are defined and used. Knowledge is power, which students can draw on when debunking fake news in mainstream and social media. They can then spread this knowledge among their family and community.

Epidemiology of Diseases

The epidemiology of diseases should also be infused in science curricula (Bracken, 2014). Epidemiology is a branch of public health that studies the (a) patterns and determinants (causes, risk factors); (b) distribution (who, when, where, and how); and (c) control of health-related states and events (not just diseases) in specified populations. Learning about epidemiology enhances middle school students' scientific literacy, epidemiological reasoning, critical thinking, problem-solving skills, and evidence-based personal health decisions (Cordell et al., 2017; Kaelin et al., 2007). With knowledge of the causes and risk factors of pandemic and epidemic diseases as well as their worldwide distribution, Saudi middle school students would be better prepared to prevent themselves, household, and community members from contracting and spreading said diseases.

Scientific Literacy

Science educators must not avoid teaching about global pandemics. Students must be scientifically literate about these issues. Various interpretations exist of what constitutes scientific literacy (Laugksch, 2000), which is synonymous with the public's level of understanding science (DeBoer, 2000). Laugksch (2000) described scientific literacy as being learned, competent, and able to minimally function in society relative to scientific matters.

Respectively, *learned* means awareness of the existing body of scientific knowledge and the way of thinking in the natural sciences. *Competent* pertains to a shared core of science content and processes, including the ability to (a) carry out tasks such as reading science-related newspaper articles and understanding reports and popular media discussions of science issues; (b) solve practical problems related to food, health, and shelter; (c) think critically and independently to sensibly deal with problems involving evidence, quantitative considerations, and logical arguments; and (d) appreciate the impact of science and technology on society (DeBoer, 2000; Laugksch, 2000; Miller, 1983). *Functioning minimally* in society means feeling confident and making good decisions when it comes to science-related concerns in everyday life such as diet, smoking, exercise, and vaccinations (Laugksch, 2000; Miller, 1983).

Unfortunately, teacher preparation and school science curricula focus mainly on scientific content contained in state-approved textbooks, which tend to eschew everyday-life applications of scientific knowledge (DeBoer, 2000). For students to make informed decisions about socio-scientific and science-related issues in their everyday life (especially during a prolonged global pandemic), science teachers must fully understand both medical terminology and epidemiology (especially about COVID-19) so they can teach them and use related pedagogy to enhance students' scientific literacy.

Pedagogical Knowledge

Shulman (1987) proposed that teachers' knowledge comprises seven dimensions: curriculum knowledge; content knowledge (unique to disciplines); general pedagogical knowledge (GPK); pedagogical content knowledge (PCK); knowledge of learners and their characteristics; knowledge of educational contexts; and philosophical knowledge. Speaking generally, GPK refers to goals and objectives, lesson planning, instructional strategies, classroom management, learning environment organization, questioning, and assessment and evaluation (Lederman & Gess-Newsome, 1992; Shulman, 1987).

Of interest to this study is Shulman's (1987) PCK dimension, which is a blend of content *and* pedagogy. It pertains to each teacher's understanding of and expertise in melding subject matter content with how to teach that content (pedagogy) and their appreciation that the six other types of knowledge inform PCK (Lederman & Gess-Newsome, 1992; van Driel et al., 1998). PCK is "the ways of representing and formulating the subject [matter content] that make it comprehensible to others" (Shulman, 1986, p. 9) through the most useful forms of representations of ideas and the most powerful analogies, illustrations, examples, explanations, and demonstrations (i.e., pedagogy) (Shulman, 1987). Veal and Makinster (1999) further proposed *domain*-specific PCK and *topic*-specific PCK.

Teachers who have topic-specific knowledge possess concepts and teaching skills and instructional methods unique to a particular topic (Magnusson & Krajcik, 1993). This study created and delivered a workshop for Saudi middle school inservice science teacher to help them purposefully develop topic-specific PCK around COVID-19 including (a) content knowledge (e.g., medical terminology, epidemiology, global pandemics) and (b) pedagogical knowledge (e.g., conceptual change strategies, mind maps, project-based learning [PBL]). The intent was to inspire and enable teachers to add COVID-19 content to their science curricula so students are more scientifically literate around this science-laden issue.

Conceptual Change Strategies

Workshop attendants were expected to gain an appreciation for what constitutes conceptual change, so they can better appreciate the change students must experience to augment their scientific literacy for COVID-19. This change can be distinguished along three dimensions: belief revision, mental model transformation, and categorical shift (Chi, 1992). Respectively, (a) refuting false beliefs can lead to belief revision, (b) the accumulation of belief revisions can lead to transformations in flawed mental models and (c) correctly categorizing deeply entrenched false beliefs and flawed mental models can lead to conceptual change. Per the latter, any two categories that differ in *kind* are said to be in conflict thus causing scientific misconceptions, false scientific beliefs, and false scientific mental models. Conceptual change requires a categorical shift wherein the conflict is removed (Chi, 1992).

Also, many science concepts are difficult to learn because they are embedded within naïve everyday experiences. Learning them thus involves radical conceptual change and ontological shifts (Chi, 1992; Inagaki & Hatano, 2003). Inagaki and Hatano (2003) suggested instruction-induced conceptual change, which requires systematic instruction and intentional top-down learning mechanisms rather than spontaneous conceptual change that takes place naturally (Vosniadou, 2007). In that spirit, the workshop herein was designed to instruct participants about and induce their own conceptual change, so they can strive for it in their teachings.

Piagetian and Vygotskian stage and strategy approaches to conceptual change are domain *general*. Domain-*specific* approaches focus on the description and explanation of the changes that take place in the content and structure of knowledge with learning and development as well as on mechanisms and strategies that are specific to these changes (Vosniadou et al., 2008). Domain-specific change requires learning environments that support active learning (Vosniadou et al., 2001). This means learners participate in projects, problem solving, and thinking about their ideas and their mental models within real-world contexts so they can express their own beliefs or mental representations of science concepts. To that end, the intervention herein taught teachers how to utilize PBL and mind maps to facilitate students' conceptual change regarding medical terminology and epidemiology as it pertains to COVID-19.

Educators' Role Relative to Students' Health Knowledge

Teachers are the cornerstone of the educational process, and most are open to any change that benefits students (Makhlouf, 2021). It is thus important to orient educators to recommended curricular changes because if they believe in the importance of change, they are more likely to advocate for it (Aldahmash et al., 2019). COVID-19 is a health issue—life or death. Beyond the job requirements of doctors, health practitioners, and workers in the medical and health fields, health knowledge has become a requirement for everyone including teachers and middle school students. Of special importance is ensuring that educators hold this knowledge so they can teach students to seek reliable and trustworthy health knowledge. The authors were convinced that middle school science teachers can play an important role in guiding students to behavior that avoids disease and preserves health.

Thus, investing in inservice teachers' professional development (PD) is important (Aldahmash et al., 2019). To that end, the researchers were interested in assessing Saudi middle school inservice science teachers' cognitive gains relative to medical terms and epidemiology before and after completing a purposefully designed workshop. The researchers especially focused on gains along three cognitive levels of learning: knowledge, comprehension, and application (Anderson & Krathwohl, 2001). And some teachers were interviewed to gain insights into their experiences with teaching what they had learned in the workshop.

Research Question

One research question guided this mixed methods research design: *What is Saudi middle school inservice science teachers' cognitive gain from and experience with using what was learned in a training program about medical terms (epidemics and pandemics) and epidemiology*? Table 1 summarizes the strand-specific research questions, data sources, and data analysis techniques with details provided in the "Method" section.

Method

Conducted between August 2020 and June 2021, the study employed a mixed methods research design. This approach was considered the best way to (a) gain understandings of inservice teachers' experience with learning about and teaching scientific concepts about medical terminology (epidemics and pandemics) and epidemiology and (b) identify potentially relevant variables that can be quantitatively tested in the future (Hoepfl, 1997). To ensure data integration to answer the research question, a sequential, connected design was used that involved pre and posttest quantitative data followed with qualitative semi-structured interview data. The former informed data collection protocol for the latter (Creswell & Plano Clark, 2007). The research design achieved expansion triangulation, wherein qualitative data helped answer any questions that arose during the quantitative strand, yielding further elucidation (Aarons et al., 2012).

In more detail, the research design protocol comprised five steps. First, the lead author developed a training program (curriculum and workshop protocol) about medical terminology and epidemiology that experts then validated. Second, a pre and posttest instrument was created. Third, it was first administered (pretest) to Saudi middle school inservice science teachers just before starting the workshop. Fourth, the workshop was delivered and followed with a posttest assessment of cognitive gains. Fifth, several months after the last workshop session, a small sample of teachers was interviewed about their experience teaching students using the learned content. After the intervention (workshop curriculum and protocol) is explained, the key steps in any research design process are presented with respective quantitative and qualitative strand details (Creswell & Plano Clark, 2007; McGregor, 2018).

Intervention: Curriculum and Workshop Development

The researchers proposed that the science curricula must inculcate preventive awareness among learners vis-à-vis global pandemics and do so by incorporating related scientific concepts and issues into inservice teachers' PD. To that end, the lead author developed a curriculum called (translated from Arabic to English) *Strategies and content for middle school science inservice teachers to use when teaching medical terminology and epidemiology scientific concepts*. Science education professors and a medical doctor vetted the curriculum to ensure content validity.

The workshop comprised three, 4 h sessions delivered over three consecutive days (see Table 2). Session one included the (a) definition of preventive medicine, its objectives, and various levels and (b) the definition of and differences between an epidemic and a pandemic and the preventive measures to deal with them. Session two explored two

Table 1 Strand-specific research questions, data sources, and analytical techniques

Strand-specific research questions	Data source	Data analysis technique
Quantitative strand: is there a statistically significant difference in Saudi middle school inservice science teachers' cognitive gains before and after receiving a training program about medical terms (epidemics and pandemics) and epidemiology?	Pre- and posttests	*t* test and descriptive statistics
Qualitative strand: what was the experience of Saudi middle school inservice science teachers 4 months or longer after teaching students using this new knowledge about medical terms (epidemics and pandemics) and epidemiology?	Semi-structured interviews	Thematic analysis

Table 2 Overview of intervention (curriculum and training program workshop) to teach Saudi middle school inservice science teachers about medical terminology and the epidemiology of diseases (COVID-19)

Session length	Session topics	Session title	Session number
4 h	- Medical terminology - Epidemics and pandemics	Introduction to medical terminology and epidemiology	First
4 h	- Spanish flu - Bird flu - COVID-19	Global pandemics	Second
4 h	- Conceptual change strategies - Mind maps - Project-based learning (PBL)	Strategies for presenting scientific concepts to students	Third

previous pandemics and the current pandemic—COVID-19. The third session included learner-centered, active-learning strategies for presenting content and helping students learn these new scientific concepts. Each session included session objectives, the organizational framework for the content, an introductory activity, and the delivery of the content. A copy of the curriculum is available on request, albeit in the Arabic language.

For clarification, exposure to the *pedagogical* aspect of the curriculum (how to teach about COVID) occurred along two fronts—(a) the actual teaching of the three strategies along with (b) the instructor modeling them as she taught the workshop. Participants thus learned about the theory of conceptual change, mind mapping, and PBL while benefiting from social learning—they experienced the strategies being used to deliver the *content* of the workshop.

Quantitative Sample Frame

In late summer 2020, the Continuing Education Center at XXX, a major Saudi Eastern Province university, promoted the workshop to Saudi Arabian teachers by sending the lead author's prepared email invitation. Amid the distracting pandemic, a total of 86 female inservice teachers from across KSA registered to complete the workshop. They held a Bachelor of Science degree in zoology, botany, biology, or life science or in the pedagogical sciences (e.g., educational psychology, curriculum, or teaching methods). They had varied classroom experience teaching junior and senior high school female students and ranged in age from 30 to 45. Participation was voluntary. Anonymity was assured.

Qualitative Sample Frame

After the workshop was completed, the lead researcher waited 4 months and then emailed all 86 workshop participants inviting them to partake in semi-structured interviews to explore their experience with teaching middle school science students using the workshop's content. Eleven participants volunteered for the qualitative phase of the study. They were Saudi female middle school (grades 6–9) inservice science teachers: botany, biology (life sciences), and zoology. The response rate (13%) and sample frame ($N = 11$) met the limit required to stave off validity concerns in mixed methods research designs when participants are involved in both strands (Creswell & Plano Clark, 2007).

Data Collection Instruments

The mixed methods research design entailed (a) a quantitative pre and posttest instrument and a (b) qualitative semi-structured interview protocol.

Quantitative Strand: Pre- and Posttest Instrument

A pre-/posttest instrument was developed for application before and after the workshop. It measured changes along three levels of the cognitive learning domain: knowledge, comprehension, and application (18 questions in total). Part 1 included 15 multiple choice questions with four choices each. Seven questions assessed knowledge and eight assessed comprehension. Every correct answer received one point (15 points in total). The second part included three items that assessed application through practical situations related to teaching medical terminology and epidemiology. Valued at five points each, this part totaled 15 points equating to 30 points in total for the instrument. The full instrument is available on request.

In more detail, *knowledge* questions related to ideal disease prevention levels, causes of epidemics, influenza patterns, repositories for virus subtypes, virus incubation periods, drug efficacy, and Stepans' (2008) conceptual change theory. *Comprehension* questions pertained to geographic disease spread, influenza virus transmission, requirements for a pandemic, virus outbreaks in animals and birds, preventive medicine, epidemiology, and more on Stepans' (2008) conceptual change theory. *Application* questions focused on preventative measures for epidemics and pandemics, PBL to teach medical terminology and epidemiology, mind mapping, and the application of conceptual change strategies.

Three expert professors (medicine and science education) validated the instrument based on scientific authenticity, suitable language, and accurate terms. The instrument was revised using their feedback with these two steps taken as evidence of internal validity (i.e., the instrument measured what it was intended to measure) (McGregor, 2018). Regarding internal consistency, no questions were deleted after piloting the instrument with 50 male and female Saudi science inservice teachers. Correlation coefficients for each question ($N = 18$) and the overall test score ranged from 0.565 to 0.870 ($p < 0.01$) (see Table 3). Internal consistency was achieved between the overall cognitive domain test score and three levels of cognitive learning measured in this study: knowledge (0.941), comprehension (0.954), and application (0.889) ($p < 0.01$).

Cronbach's alpha was calculated in the pilot study to determine the stability of the pre and posttest instrument as well as the value of Cronbach's alpha stability factor in the case of deleting one item (see Table 4). A Cronbach's alpha 0.924 indicated a very stable instrument relative to questions 1–15. Regarding questions 16–18, a Pearson coefficient (0.853) and the Gettmann coefficient (0.873) (split-half method) affirmed the instrument's stability on the application level of learning as well.

Qualitative Strand

The research team developed a set of demographic-related questions and a set of semi-structured interview questions to obtain further insights into the inservice science teachers' real-time lived experience with teaching workshop content to middle school science students. Four referees with science education backgrounds validated the interview questions. Questions included but were not limited to (a) Did you teach scientific concepts about COVID-19? If not, why not? (b) If taught, what kind of concepts did you introduce and what kind of difficulties did you have? (c) What understandings about COVID-19 were important for you to know about before you taught these concepts? (d) What (if any) active learning activities did you introduce? (e) Did you include COVID-related activities to help students learn about scientific ways to understand the pandemic? (f) How did you make the classroom a place to introduce correct information to offset rumors and misconceptions? (g) What kind of COVID connections (if any) were made between students' learning and home and community?

Table 4 Cronbach's alpha stability factors for knowledge and comprehension levels of learning

Knowledge		Comprehension	
Question number	Cronbach's alpha if term is deleted	Question number	Cronbach's alpha if term is deleted
1	0.915	2	0.921
4	0.921	3	0.921
5	0.917	7	0.920
6	0.918	9	0.922
8	0.0.921	11	0.921
10	0.915	12	0.921
14	0.916	13	0.916
		15	0.919

Cronbach's alpha stability factors for knowledge and comprehension levels of learning 0.924

Data Collection

Quantitative Strand: Intervention Pre- and Posttest Questionnaire

The online workshop was delivered late summer 2020 in the Eastern Province of Saudi Arabia conveniently chosen because the lead author, who delivered the training and collected the data, was employed in this region. Over the course of 3 days, the lead author delivered 3, 4 h sessions. The pretest was administered online a few hours before the workshop began. The posttest was administered online a

Table 3 Internal consistency correlation coefficients for the test items (questions) per cognitive level of learning and the total test score ($p < 0.01$)

Knowledge (memory and recall) Correlation coefficient **.941		Comprehension (understanding) Correlation coefficient **.954		Application Correlation coefficient **.889	
Question number	Correlation coefficient	Question number	Correlation coefficient	Question number	Correlation coefficient
1	**.788	2	**.600	16	**.687
4	**.567	3	**.609	17	**.687
5	**.751	7	**.719	18	**.565
6	**.737	9	**.578		
8	**.594	11	**.623		
10	**.770	12	**.626		
14	**.739	13	**.780		
		15	**.683		

few hours after the entire 3-day workshop was completed ($N=86$).

Qualitative Strand: Semi-structured Interviews

Semi-structured interviews ($N=11$) were administered (2021) up to 9 months after the workshop had concluded. This time frame afforded participants the opportunity to teach the scientific conc`epts they had learned. The lead author conducted individual, approximately 30-min, audio-taped interviews in Arabic via telephone or using Zoom. Informed consent was obtained. Anonymity was assured.

Data Analysis

Quantitative Strand

Pre and posttest questionnaire data were analyzed using descriptive (frequencies, percentages, means, range, standard deviation [SD]), and inferential (*t* test) statistics. *t* tests are often used in pre and posttest research designs to see if groups are different after an intervention (McGregor, 2018).

Qualitative Strand

One author summarized the Arabic version of the transcribed interview data for each question. Questions posed and unscripted prompts differed from person to person because, as is allowed with this type of interview, not all prepared questions were asked nor in the same order. Questions were instead used to guide the conversation (Leech, 2002). All authors then employed iterative readings of this amalgamated data set to generate a collection of agreed-to common threads. An expert translator checked the English translation of the Arabic-language thematic findings. This protocol better ensured that meaning and cultural expressions and concepts were captured (Suh et al., 2009). Quotes and researchers' interpretations are tendered to provide evidence of the themes being proposed (McGregor, 2018).

Results and Findings

A mixed methods research design yields quantitative results (numbers) and qualitative findings (words) (McGregor, 2018). Both strands added insights into the impact of an intervention designed to teach Saudi middle school inservice science teachers how to teach medical terminology (epidemics and pandemics) and epidemiology vis-à-vis COVID-19. Empirical results are reported separately. Qualitative findings are presented briefly with details woven into the discussion to further elucidate quantitative results (Aarons et al., 2012). This reporting protocol respects the principle that "researchers [should] create their own approaches and presentation styles that best fit their mixed research studies" (Leech, 2012, p. 873).

Quantitative Results

The quantitative strand queried "Is there a statistically significant difference in Saudi middle school inservice science teachers' cognitive gains before and after receiving the training program about medical terms (epidemics and pandemics) and epidemiology?" The answer is unequivocally *yes*. The workshop training program improved Saudi inservice science teachers' abilities to teach medical terminology and epidemiology in middle school science classes.

There were statistically significant results for pre and posttest scores overall and on all three levels of learning within the cognitive domain. Regarding the former, out of a possible score of 30, posttest scores *overall* (mean = 26.26, SD 2.83) were significantly higher than pretest scores (mean = 12.62, SD 6.35) with a posttest t value of 18.51 ($p < .01$). The pretest *knowledge* score (possible 7) was mean = 2.12 (SD 2.53) compared to the posttest score of mean = 5.72 (SD 0.835) ($p < .01$). The pretest *comprehension* score (possible 8) was mean = 2.96 (SD 3.17) compared to the posttest mean = 7.50 (SD 0.942) with a posttest t value of 12.81 ($p < .01$). The pretest *application* score (possible 15) was mean = 7.53 (SD 1.50) compared to the posttest mean = 13.05 (SD 2.38) with a posttest t value of 18.05 ($p < .01$).

A significant p value (present in these results) indicates that the intervention worked, but an effect size coefficient indicates *how much* it worked—small, medium, or large effect (McLeod, 2019). The high values of the effect size coefficient $n2$, where all values exceeded the high impact limit of 0.14, indicate that the program had a large effect on participants' cognitive gains. On average, in the posttest, participants virtually always correctly (95%) answered knowledge questions ($n=7$) with scores ranging from 89.5 to 100%. The same pattern held for comprehension questions ($n=8$) (94%, ranging from 86 to 99%) and application questions ($n=3$), which scored somewhat lower (86%) but still at a high level.

Qualitative Findings

Empirical results affirmed that the intervention worked (statistically significant results), and it had a large effect on participants' cognitive gains. The qualitative strand explored "What was the experience of Saudi middle school inservice science teachers 4 months or longer after teaching students using this new knowledge about medical terms (epidemics and pandemics) and epidemiology?" Overall, participants agreed that it was important to teach about COVID-19, and several noted that students also felt it was important to learn about it. Evelyn commented that "the topic was of much more interest to my grade 9 students than any other topic in the assigned curriculum." A thematic analysis generated one overarching theme and several subthemes.

The overarching theme was that participants reported both positive and negative lived experiences with teaching what they had learned. Regarding the subthemes, their positive experiences included (a) student engagement with the curriculum, (b) community connections via PBL, (c) opportunities to teach colleagues about COVID-19, and (d) proposing a pandemic unit for administrative approval. Negative experiences concerned (a) a lack of time to teach new content in an existing program of study; (b) obligations to teach the current curriculum during the pandemic despite what they had learned being *about* the pandemic; and (c) administrative resistance to both adding new content to the current, state-approved curriculum and teaching about COVID-19. More evidence is presented in the discussion section with a general overview now shared (Araons et al., 2012; Leech, 2012).

On a positive note, Carema was excited about the chance to engage students with COVID-related material. "Students were introduced to concepts through research that encouraged their investigation. They were exposed to theoretical and applied research, ancient and modern." Doria intentionally taught "scientific methods of preventive diseases and illnesses… and students learned about epidemics that appeared in the past." Badira said that while teaching online, she "sent website links about specific scientific concepts … and videos about COVID awareness … and other videos that instigated classroom discussion."

Regarding the negative issues of lack of time and administrative resistance, Amal said "students were very much into this topic. I wish I had more time to delve into more details." Administrative resistance is reflected in Badria's comment that "school administrators were pushing and pressing to have the traditional content covered regardless of how timely the COVID topic is." In disbelief, Carema said, "the school leader wanted to make sure that all of the time be devoted to cover the textbook. I was told that any topic about the pandemic was not our focus in the science classroom!".

Discussion and Implications

Per the quantitative strand, *t* test scores indicated significantly improved ($p < .01$) cognitive gains overall and along three levels of learning after completing the workshop. The intervention worked very well. Using accurate (expert-vetted) information about medical terminology, epidemiology, and global pandemics, the intentional instruction-induced, active-learning approach (Inagaki & Hatano, 2003; Vosniadou, 2007) succeeded in augmenting participants' knowledge base and scientific literacy. The marked difference in pre- and posttest mean scores was evidence of this change, which improved 103% overall with noticeable gains along all three levels of cognitive learning measured in this study (see Table 5).

Participants were better prepared to teach students and enhance their scientific literacy about COVID-19 after attending the workshop. Said another way, empirical evidence suggested that participants bolstered their *topic*-specific PCK regarding COVID-19 (Veal and Makinster, 1999). PCK is a blend of content *and* pedagogy. It pertains to each teacher's understanding of and expertise in melding content *with* how to teach that content (pedagogy) (Shulman, 1987). As planned (Inagaki & Hatano, 2003; Vosniadou, 2007), in addition to new information and content knowledge, the intervention provided opportunities to learn new instructional strategies to teach COVID-19 (e.g., conceptual change strategies, mind maps, and PBL). The intent was to cement the pedagogy aspect of PCK (Shulman, 1986, 1987) for medical terminology and the epidemiology of diseases. The high overall posttest mean score (25.62/30 $p < .01$) affirmed that participants learned both the content and pedagogy taught in the workshop.

Statistically significant differences in pre and posttest mean scores (see Table 5) strongly suggested that conceptual change, as Chi (1992) conceived it, had occurred for participants. It appears that they likely experienced some degree of belief revision, mental model revision, and perhaps even categorical shifts vis-à-vis medical terminology and epidemiology relative to COVID-19. As an example, Basma said that while she was teaching, "I corrected negative stereotypes about COVID-19." Architects of future studies employing likeminded interventions are encouraged to purposefully operationalize Chi's (1992) model of conceptual change so they can identify participants' false beliefs, flawed mental models, and categorical errors and then measure any revisions and corrections aside from using statistical tests to measure cognitive gain (Hoepfl, 1997).

Table 5 Saudi middle school inservice science teachers' percentage change in cognitive learning gains after completing an intervention to learn about medical terminology and the epidemiology of diseases

Cognitive domain and level of learning	Possible mean score ($p < .01$)	Pretest mean ($p < .01$)	Posttest mean ($p < .01$)	Percentage change
Overall cognitive gain	30	12.62	25.62	103%
Knowledge	7	2.12	5.72	170%
Comprehension	8	2.96	7.50	153%
Application	15	7.53	13.05	73%

The qualitative strand concerned teachers' experiences with teaching the newly learned PCK (content and pedagogy) relative to medical terminology and the epidemiology of diseases. High post-test mean scores (25.62/30, $p < .01$) affirmed that participants learned the workshop content, understood it, and could apply it. The thematic analysis revealed that their experience with using this new knowledge and pedagogy in their classrooms was both positive and negative in nature. Some participants said they had successfully taught students and colleagues about pandemics and COVID-19. Sally reported that "in my course, most students were engaged and comprehended the differences between epidemic and pandemic." Basma said, "I was able to teach about COVID-19." Nerjes commented, "I taught my students and colleagues using what I had learned." Rana similarly said, "I used the workshop content to teach my coteachers."

Other participants lamented that they did not have enough time to teach what they had learned in the workshop because they had to cover the regular science curriculum during the pandemic. Some participants judged the regular curriculum uninteresting and completely immaterial to COVID-19. To illustrate, despite wanting to teach what she had learned, Amina "unfortunately, had to shift to boring subjects irrelevant to the timely topic of COVID 19." This comment reflects the irony of not having time to teach the workshop content during the pandemic despite that it pertained *to* the pandemic. Nancy also said, "I had no time to use what I had learned in the workshop, because I had to cover the course content." Amina agreed, "I wish I had the time to do more on this new topic."

This 'time-available-to-teach' subtheme is telling in that it threatened scientific literacy, which is closely linked with students' ability to apply scientific concepts in everyday life (Laugksch, 2000; Miller, 1983). Studying about epidemiology enhances middle school students' scientific literacy (Cordell et al., 2017; Kaelin et al., 2007). But students cannot become literate in scientific concepts that they do not have an opportunity to learn. Confusing messaging and media misinformation are dramatically impacting students' everyday lives and mental health (Sayed et al., 2021; Zakout et al., 2020). Insufficient time to deliver a modified curriculum to address this reality disadvantaged students.

On another front, some participants who wanted to improve students' scientific literacy about this issue felt administratively confined in their efforts as exemplified in Rana's comment, "My principal objected to any talk about COVID-19, so I could not teach this." As noted, others said they were required to teach the mandated curriculum without including revisions to accommodate COVID-19. Amana had to "unfortunately [teach the approved curriculum, which] had no relevance to COVID-19."

Implications

These mixed method results and findings have implications. First, teachers are usually open to curricular changes that benefit students (Makhlouf, 2021), intimating they are open to the conceptual change required to augment their *own* scientific literacy so they can then teach students. To make this link more explicit, information about the *scientific literacy construct* could be added to the workshop curriculum. Teachers who appreciate the link between scientific literacy and everyday-life concerns will feel more confident about and when making curricular decisions around COVID-19 and encouraging students to become scientifically literate in this area (Laugksch, 2000; Miller, 1983). Horiya recounted that "students did their project using what they learned with me about COVID-19." She taught them PBL, which they undertook using workshop knowledge she had gained and then taught them.

Second, findings revealed that some participants who appreciated the importance of teaching the workshop's content encountered administrative barriers. As noted, Rana said, "my principal objected to any talk about COVID-19, so I could not teach this." Jorgenson (2006) claimed that teachers, school boards, and administrators are best suited to slow change. Expecting administrators to shift gears so quickly (i.e., add new content to an already approved science curriculum) goes against their normal predisposition to slow-oriented change. The workshop curriculum could be expanded to teach participants how to anticipate and cope with administrative resistance so that middle school science students have a better chance of becoming more scientifically literate around COVID-19-related science content.

Examples might include teaching workshop participants about advocacy and lobbying skills and change management strategies so they can respectively (a) make and present a strong case for teaching COVID-19 related content in middle school science classes and (b) change administrators' perspectives and positions (i.e., better manage the fast change involved in adding curricular content to an existing program of study) (Jorgenson, 2006). Teachers who believe in the importance of a curricular change are more likely to advocate for it (Aldahmash et al., 2019) and deal with any resistance.

To illustrate, Nerjes affirmed that she had "put forth a proposal to school administrators to implement a unit on the pandemic and COVID-19." The Saudi Ministry of Education (2021) recently increased the enrichment, application, and exercise aspect of science curricula intimating there is room for COVID-19-related efforts. With the pandemic affecting all of humanity (Tanveer et al., 2020), it is imperative that medical terminology and the epidemiology of diseases be introduced into the Saudi middle school science curriculum.

This strategy increases the likelihood of internalizing values they can use in their young and mature adult everyday lives (Idris et al., 2012) when facing future epidemics and pandemics.

Third, on a related note, another objective of this intervention was connecting newly gained knowledge with home and community. The intent was for Saudi middle school students to become more scientifically literate about medical terminology and epidemiology and then take this learning to their family and into their neighborhood and local community (Almudara, 2019) all of whom were experiencing deep COVID-19-induced stress (Sayed et al., 2021; Zakout et al., 2020). Sharing this knowledge would hopefully slow the spread of the disease. Qualitative findings indicated that this happened in some instances as exemplified through Maram's experience. "Using what I taught them, my students did community service to teach their siblings and neighbors about COVID-19."

Limitations

Future studies should continue to use the mixed methods research design because it generated a rich combination of quantitative and qualitative insights into the phenomenon. In the future, sampling should occur across all 13 KSA provinces. Researchers are encouraged to sample both female and male inservice teachers and conduct gendered analyses of cognitive gains and lived experiences with teaching medical terminology and epidemiology to middle school as well as to senior high students, again both male and female. Both natural science and pedagogical science teachers should be included. Preservice science teachers could be compared with inservice teachers. Future studies could focus on the other cognitive levels of learning: analysis, evaluation (critically create and justify positions), and creativity (synthesis).

Conclusion

Scientifically literate people have an appreciation for the impact of science on society and are confident when dealing with contentious science-laden issues and sharing what they have learned (Laugksch, 2000; Miller, 1983). This modest but effective workshop, which taught Saudi science inservice teachers how to teach COVID-19-related content in the middle school science curriculum, appeared to contribute to this aspect of scientific literacy suggesting the training should be offered on a wider basis in the KSA. Impressive, statistically significant cognitive gains were recorded in conjunction with positive and negative lived experiences with teaching what had been learned.

Youth must be scientifically literate about pandemics because history tends to repeat itself. The next generation must be better prepared for this eventuality. Changing middle school science curricula and pedagogy so students can learn about medical terminology and epidemiology would contribute to this preparedness. Study outcomes especially support the recommendations that Saudi educational policy makers respect the importance of (a) infusing middle school science curricula with up-to-date scientific information that prepares youth to face similar challenges with relevant and timely health knowledge, (b) training the trainers, and (c) administrative support and time for well-reasoned but impromptu curricular modifications in the new face of global pandemics.

Acknowledgements We would like to acknowledge the inservice teachers as well as the Continuing Education Center at XXX and its administrative staff that helped distribute the internet link for the pre and posttest instrument.

Funding The work was not funded.

Declarations

Ethics Approval Ethical approval was obtained.

Consent to Participate Obtained from participants prior to participation.

Conflict of Interests The authors declare that they have no conflict of interest.

References

Aldahmash, A., Alamri, N., Aljallal, M., & Bevins, S. (2019). Saudi Arabian science and mathematics teachers' attitudes toward integrating STEM in teaching before and after participating in a professional development program. *Cogent Education*, *6*(1), Article 1580852. https://doi.org/10.1080/2331186X.2019.1580852

Almudara, S. B. (2019). An observation study of 2030 vision in primary and secondary schools in Saudi Arabia. *Euromentor Journal, 10*(1), 51–63.

Alsofayan, Y. M., Althunayyan, S. M., Khan, A. A., Hakawi, A. M., & Assiri, A. M. (2020). Clinical characteristics of COVID-19 in Saudi Arabia: A national retrospective study. *Journal of Infection and Public Health, 13*(7), 920–925. https://doi.org/10.1016/j.jiph.2020.05.026

Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Longman.

Aarons, G. A., Fettes, D. L., Sommerfeld, D. H., & Palinkas, L. A. (2012). Mixed methods for implementation research: Application to evidence-based practice implementation and staff turnover in community-based organizations providing child welfare services. *Child Maltreatment, 17*(1), 67–79. https://doi.org/10.1177/1077559511426908

Bracken, M. B. (2014). Epidemiology as a liberal art: From graduate school to middle school, an unfulfilled agenda. *Annals of Epidemiology, 24*(3), 171–173. https://doi.org/10.1016/j.annepidem.2013.11.010

Chi, M. T. H. (1992). Conceptual change within and across ontological categories: Examples from learning and discovery in science. In R. Giere & H. Feigl (Eds.), *Cognitive models of science* (pp. 129–186). University of Minnesota Press.

Cordell, R., Cordeira, K., Cohen, L., & Bensyl, D. (2017). Building the pipeline: Programs to introduce middle school, high school, medical, and veterinary students to careers in epidemiology and public health. *Annals of Epidemiology, 27*(11), 752–755. https://doi.org/10.1016/j.annepidem.2017.09.010

Creswell, J., & Plano Clark, V. (2007). *Designing and conducting mixed methods research*. Sage.

DeBoer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching, 37*(6), 582–601. https://doi.org/10.1002/1098-2736(200008)37:6%3c582::AID-TEA5%3e3.0.CO;2-L

Hoepfl, M. C. (1997). Choosing qualitative research: A primer for technology education researchers. *Journal of Technology Education*, *9*(1), 47–63. https://doi.org/10.21061/jte.v9i1.a.4

Idris, F., Hassan, Z., Ya'acob, A., Gill, S., & Awal, A. (2012). The role of education in shaping youth's national identity. *Procedia – Social and Behavioral Sciences, 59*, 443–450. https://doi.org/10.1016/j.sbspro.2012.09.299

Inagaki, K., & Hatano, G. (2003). Conceptual and linguistic factors in inductive projection: How do young children recognize commonalities between animals and plants? In D. Gentner & S. Goldin-Meadow (Eds.), *Language in mind* (pp. 313–333). MIT Press.

Jorgenson, O. (2006). Why curriculum change is difficult and necessary. *Independent School Magazine, 6*(4), 66–79.

Kaelin, M. A., Huebner, W. W., Nicolich, M. J., & Kimbrough, M. L. (2007). Field test of an epidemiology curriculum for middle school students. *American Journal of Health Education, 38*(1), 16–31. https://doi.org/10.1080/19325037.2007.10598938

Kari, J. A., Shalaby, M. A., Albanna, A. S., Alahmadi, T. S., Sukkar, S. A., MohamedNur, H. A., & Alhasan, K. A. (2021). Coronavirus disease in children: A multicentre study from the Kingdom of Saudi Arabia. *Journal of Infection and Public Health, 14*(4), 543–549. https://doi.org/10.1016/j.jiph.2021.01.011

Laugksch, R. C. (2000). Scientific literacy: A conceptual overview. *Science Education, 84*, 71–94.

Lederman, N. G., & Gess-Newsome, J. (1992). Do subject matter knowledge, pedagogical knowledge, and pedagogical content knowledge constitute the ideal gas law of science teaching? *Journal of Science Teacher Education, 3*(1), 16–20. https://doi.org/10.1007/BF02614732

Leech, B. L. (2002). Asking questions: Techniques for semistructured interviews. *PS: Political Science & Politics*, *35*(4), 665–668. http://links.jstor.org/sici?sici=1049-0965%28200212%2935%3A4%3C665%3AAQTFSI%3E2.O.C0%3B2-T. Accessed 30 January 2021.

Leech, N. L. (2012). Writing mixed research reports. *American Behavioral Scientist, 56*(6), 86–881. https://doi.org/10.1177/0002764211433800

Magnusson, S., & Krajcik, J. S. (1993). *Teacher knowledge and representation of content in instruction about heat energy and temperature.* Paper presented at National Association for Research in Science Teaching Annual Meeting, Atlanta, GA. https://files.eric.ed.gov/fulltext/ED387313.pdf. Accessed 13 April 2021.

Makhlouf, A. (2021). Saudi schools' openness to change in light of Vision 2030. *American Journal of Educational Research, 9*(1), 52–60. https://doi.org/10.12691/education-9-1-6

McGregor, S. L. T. (2018). *Understanding and evaluating research*. Sage.

McLeod, S. A. (2019). What does effect size tell you? *Simply Psychology*. https://www.simplypsychology.org/effect-size.html. Accessed 10 January 2021.

Miller, J. D. (1983). Scientific literacy: a conceptual and empirical review. *Daedalus, 112*(2), 29–48. https://www.jstor.org/stable/20024852. Accessed 20 August 2021.

MNT Team. (2020). What to know about pandemics. *Medical News Today*. https://www.medicalnewstoday.com/articles/148945. Accessed 10 January 2020.

Saudi Ministry of Education. (2021). *The Ministry of Education continues dispatching more than 71 million textbooks to education directorates in preparation for the next academic year* [Press release]. https://www.moe.gov.sa/en/mediacenter/MOEnews/Pages/BOOK-T-2021-12.aspx#. Accessed 30 January 2021.

Sayed, M. H., Hegazi, M. A., El-Baz, M. S., Alahmadi, T. S., Zubairi, N. A., Altuwiriqi, M. A., & Almurashi, S. H. (2021). COVID-19 related posttraumatic stress disorder in children and adolescents in Saudi Arabia. *PLoS One, 16*(8), e0255440. https://doi.org/10.1371/journal.pone.025544

Shulman, L. S. (1986). Those who understand: knowledge growth in teaching. *Educational Researcher*, *15*(2), 4–14. https://doi.org/10.3102/0013189X015002004

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1–23. https://doi.org/10.17763/haer.57.1.j463w79r56455411

Stepans, J. (2008). *Targeting students' physical science misconceptions using the conceptual change model* (3rd ed.). Saiwood.

Suh, E. E., Kagan, S., & Strumpf, N. (2009). Cultural competence in qualitative interview methods with Asian immigrants. *Journal of Transcultural Nursing, 20*(2), 194–201. https://doi.org/10.1177/1043659608330059

Tanveer, M., Bhaumik, A., Hassan, S., & Ul Haq, I. (2020). COVID-19 pandemic, outbreak educational sector and students online learning in Saudi Arabia. *Journal of Entrepreneurship Education*, *23*(3), Article 9248. https://www.abacademies.org/articles/covid19-pandemic-outbreak-educational-sector-and-students-online-learning-in-saudi-arabia-9248.html. Accessed 30 January 2021.

Taylor, M., Esbensen, B., & Bennett, R. (1994). Children's understanding of knowledge acquisition: The tendency for children to report that they have always known what they have just learned. *Child Development, 65*(6), 1581–1604. https://doi.org/10.2307/1131282

Van Driel, J. H., Beijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. *Journal of Research in Science Teaching, 38*(2), 137–158. https://doi.org/10.1002/1098-2736(200102)38:2%3c137::AID-TEA1001%3e3.0.CO;2-U

Veal, W. R., & MaKinster, J. G. (1999). Pedagogical content knowledge taxonomies. *Electronic Journal of Science Education, 3*(4), Article 2. https://ejrsme.icrsme.com/article/view/7615. Accessed 30 January 2021.

Vosniadou, S. (2007). Conceptual change and education. *Human Development, 50*(1), 47–54.

Vosniadou, S., Ioannides, C., Dimitrakopoulou, A., & Papademetriou, E. (2001). Designing learning environments to promote conceptual change in science. *Learning and Instruction, 11*(4–5), 381–419. https://doi.org/10.1016/S0959-4752(00)00038-4

Vosniadou, S., Vamvakoussi, X., & Skopeliti, I. (2008). The framework theory approach to the problem of conceptual change. In S. Vosniadou (Ed.), *International handbook of research on conceptual change* (1st ed., pp. 3–34). Routledge.

Zakout, Y. M., Alreshidi, F. S., Elsaid, R. M., & Ahmed, H. G. (2020). The magnitude of COVID-19 related stress, anxiety and depression associated with intense mass media coverage in Saudi Arabia. *AIMS Public Health, 7*(3), 664–678. https://doi.org/10.3934/publichealth.2020052