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Linking science education and HIV using viral biology, epidemiology and science practices

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Abstract

Objective: To examine the effectiveness of an interdisciplinary, discovery-oriented teaching unit designed to provide science and health information about HIV from the perspective of viral biology, population statistics and epidemiology.
Design: Single group pre- and post-curriculum pilot study.
Setting: Fifteen middle and high school classrooms recruited from districts in and around a large, diverse, urban area in the mid-southern USA.
Method: Science educators, clinicians, virologists and biologists collaborated to develop a set of five activities intended to increase content knowledge related to HIV, while developing students' science-related skills in the context of an authentic, relevant example. The activities were piloted with six hundred and twenty-four 12- to 18-year-old students. Multiple-choice pre- and post-tests were used to assess changes in students' knowledge, and teacher evaluations were used to gauge appropriateness of content, ease of activity implementation and teacher perceptions of student skill development, learning and engagement.
Results: Student pre- and post-tests and teacher post-evaluations indicated that the curriculum was effective in increasing content knowledge for students across all age ranges, with 13- to 14-year-old, grade 8 students achieving the greatest knowledge gains. Teacher-reported information also suggested that students were able to apply relevant skills to their interpretation of authentic data related to the incidence and transmission of HIV infection around the world.
Conclusion: The developed activities have the potential to provide timely, relevant information to students while strengthening science-related content knowledge and skills as well as health literacy.

Keywords

Biology, enquiry-based activities, health literacy, HIV education, secondary school, USA

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Introduction

The wide availability of effective HIV anti-retroviral drugs in the USA combined with declining infection rates in some segments of the population have led to a recalibration of perceptions about HIV and the acquired immune deficiency syndrome (AIDS) – from a death sentence to manageable chronic illness. In recent years, the enhanced availability of anti-retroviral drugs has increased the number of people living with HIV to 37 million worldwide, with around 2 million new infections and about 1.2 million deaths from AIDS-related illness in 2014 (UNAIDS, 2015). Complacency, however, is misplaced. HIV incidence remains constant at about 50,000 new infections each year in the USA, with highest rates among racial and minority ethnic populations (Centers for Disease Control and Prevention [CDC], 2012). Individuals aged 13–24 years comprised 26% of new HIV infections in the USA in 2010 (CDC, 2012).

Although numerous efforts have been made to inform and educate adolescents and young adults about HIV, the availability of science-based HIV education in US schools remains limited. When available, HIV instruction typically focuses on prevention and behaviour modification (especially abstinence) rather than disease biology and is conducted in health or physical education classes (Kirby et al., 2006). In some cases, the topic simply is not discussed at all. Nationwide, the prevalence of having been taught about HIV in school ranged from 73.1% to 87.5% in 2013, as reported in the US Youth Risk Behavior Survey (Kann et al., 2014).

Providing materials that teach about HIV from a scientific, not behavioural, perspective has the potential to deepen the understanding of students who have only been exposed to more limited aspects of HIV education (DiClemente and Jackson, 2014), and may also help introduce life science and related topics to students in a real-world context. This is particularly relevant because HIV and other significant health threats are subject to frequent misconceptions due to public misinformation and poor understanding of infectious disease. To address the gap in HIV education, we developed a unit intended to provide accurate information to students – ideally as part of a multifaceted approach to HIV education (Kirby et al., 2006) – and build their understanding of core ideas and scientific practices using the global HIV epidemic as the basis for instruction.

Over the past two decades, the search for effective treatments and preventive measures has deepened scientific understanding of retroviruses, mechanisms of disease and the immune system. These discoveries form the basis for a powerful story of team-based science that encompasses basic research in viral biology, translational research with human subjects and population-based studies of patterns of disease. We used elements of this story to create a science teaching module on HIV (Vogt and Moreno, 2012). The unit, titled *The Science of HIV/AIDS: The Virus, the Epidemic and the World*, was developed and field tested while draft versions of the US Next Generation Science Standards (NGSS; National Research Council, 2013) were under development and reflect its recommendations to incorporate the real-life application of scientific knowledge and practice into K–12 science instruction. Specifically, the science and engineering practices outlined in the NGSS (National Research Council, 2013) ask students to develop and apply skills such as developing and using models, analysing and interpreting data, and obtaining, evaluating and communicating information. In addition, students are expected to develop a deep knowledge of core scientific concepts. As noted in the NGSS (National Research Council, 2013), science practices, crosscutting concepts (such as identifying patterns or cause and effect) and disciplinary core ideas are often taught separately, rather than simultaneously through the investigation of an authentic problem, even though science teaching based on real-world examples can lead to positive gains in student learning and levels of engagement (Beardsley et al., 2011; King and Ritchie, 2013; Sumter and Owens, 2011).

Accordingly, we developed a unit that addresses both core ideas and scientific practices using an infectious disease model based on the global HIV epidemic. We selected this topic because of its ongoing relevance and public health significance for the general population and for adolescents in particular. US urban students participated in the pilot study.

Purpose

In developing *The Science of HIV/AIDS*, we had two main objectives: first, to examine the effectiveness of an interdisciplinary science teaching unit in increasing student content knowledge about the biology of retroviruses, populations affected by HIV and epidemiology, and second, to identify appropriate grade levels at which to optimise the integration of HIV-related biology content into the curriculum. The objectives were related to (a) the educational needs of students for science and health information about HIV, as described above, and (b) opportunities to develop their overall science knowledge and skills in the context of a complex scientific issue. We also intended to gain insights from teachers into the suitability of the topic and set of instructional activities for dissemination and use in a range of grade ranges and school settings.

Method

Development of The Science of HIV/AIDS*: the Virus, the Epidemic and the World*

Science educators, clinicians, virologists and other biologists at Baylor College of Medicine (BCM) helped develop the goals for this instructional unit and a second unit, titled the Science of Microbes, using a 'backwards design' process (Wiggins and McTighe, 2006). Specifically, the process began by identifying desired student outcomes, then determining acceptable evidence of acquisition of knowledge and skills, before ultimately designing educational activities aligned with the assessments and intended outcomes. Collaborators included representatives from the Center for Educational Outreach at BCM and The University of Texas Health Science Center – Houston Center for AIDS Research (CFAR), as well as local school representatives. The following broad science themes were identified and developed into learning outcomes for students as part of the unit focused on HIV: mechanisms and routes of transmission for disease agents; how the immune system fights infection; and the role of the US CDC in epidemiology and tracking of disease.

With scientific guidance from CFAR researchers, unit activities were prepared by science educators and curriculum designers and underwent numerous rounds of review and revision before being finalised. Development of the unit posed special challenges because of the limitations placed by schools and families on which content related to HIV could be covered with students. Specifically, topics related to sexual activity were excluded both due to local school district regulations and feedback from curriculum team members. Field test teachers, however, were free to address topics related to HIV prevention and sexual behaviours at their discretion in accordance with their school and district policies. The five enquiry-based activities in the unit focused on HIV and the worldwide geographic distribution of infection and related disease. Each activity included an essay with background information that created a storyline to link together the various learning activities within the unit. The essays could be used as student reading where grade and maturity levels were appropriate; for teachers' enrichment; or to integrate teaching of the unit with other subject areas, such as social studies or reading/language arts. Along with the essays, sequential activities enable students to work in teams as they learned about the biology of HIV, historical perspectives, the global HIV epidemic and current epidemiological data. An edited version of the unit is available at the following URL: http://

Table 1. Overview of *The Science of HIV/AIDS: The Virus, the Eepidemic and the World*.

Activity	Description
1	Students construct a 3-D paper model of an HIV particle to understand its structure and actual size (model is approximately 500,000 times larger than an actual HIV virus).
2	Students learn how the virus particle uses its structure to invade host cells and make copies of itself. Students view microscopic images of the HIV and discuss the cell replication process, including the use of viral RNA as template to produce DNA once the virus enters a host white cell.
3	Students calculate exponential and linear growth rates, and discuss the implications of an exponential replication rate in the context of HIV infection.
4	Students map worldwide HIV prevalence rates and identify trends present in the data.
5	Students create scientific meeting-style posters or PowerPoint® presentations that compile and present HIV data by geographic area. The essay related to this activity presents several myths and facts associated with HIV, AIDS and viral transmission.

3-D: three-dimensional; AIDS: acquired immune deficiency syndrome.

www.bioedonline.org/lessons-and-more/teacher-guides/hivaids/. Short descriptions of each of the unit's activities are provided in Table 1.

Participants

To field test activities, teachers were recruited via an email listserv from across a large urban area in the mid-southern USA. Participation was open to any area middle or high school1 teacher who was available to teach all the activities. Applications were accepted on a first-come, first-served basis, and all 17 of the applications received were accepted. Ultimately, 15 teachers from different schools completed the field test with their students. Ten of the teachers who completed the field test were in traditional public schools, while the remaining five teachers worked in nontraditional public or private schools: one in a grades 9–12 alternative school, two in nontraditional public schools (a Magnet school and a Charter school) and two in private schools. School enrolment sizes for the traditional public schools ranged from 559 to 3,418 students, with the percentage of students qualifying for free or reduced federal government lunch support ranging from 28.7% to 84.8%. Because each teacher used a current class of students to field test materials, several of the high school classrooms had multiple grade levels (i.e. 9–10, 11–12, 9–12 years). In total, 624 students participated in at least one activity. Of the participating students, 52% were Hispanic, 19% were African American, 4% were Asian and 24% White.

Procedure

All field test data were collected using researcher-assigned teacher codes, which enabled researchers to link student data with teacher data while blinding teacher identity. Student pre- and post-scores were collected and reported by teachers to the project team as sets of paired data, without student identifiers. After field-testing, each teacher completed an online post-survey about quality and ease of teaching, perceptions of student interest and engagement, appropriateness of content and observations about the effectiveness of the activities with students. All aspects of the research, including data collection, were reviewed and approved by the BCM Institutional Review Board, and since it posed no potential risk beyond normal classroom educational experiences, a waiver of consent was obtained. Teachers were provided with information about the unit, including IRB approval, during an orientation session.

Instruments

Teachers administered the same 22-item student assessment (see Online Appendix) before and after teaching the unit; however, the order of questions was different for pre- and post-intervention administrations. Three questions were based on the AVERTing HIV & AIDS Quiz (http://www.avert.org/quizzes). Unit activities and the questions used for field test pre- and post-assessments were based on understandings, research findings, disease statistics and treatments about HIV current at the time of unit development. The online version of the unit, however, was updated within the past year to maintain currency for use in classrooms. In addition, certain conventions were used throughout the unit and in the assessments. For example, CD4+ was used as a descriptor for T cells that express the surface protein CD4, in the context of laboratory screening tests that measure the number of CD4+ T lymphocytes in patients (www.AIDS.gov). Teacher feedback was gathered via an online post-survey following completion of the field test. The survey contained Likert-type rating items and open-ended questions to capture teachers' perceptions of both the ease of implementation and the instructional effectiveness of each individual activity and the unit overall.

Factors

Thompson (2004) has stated that one use of factor analysis is to create a more parsimonious model. As noted by Thompson (2004), 'using fewer variables in substantive analysis tends to conserve degrees of freedom and improve power against Type II error' (p. 5). Therefore, we conducted a factor analysis to determine how the assessment items grouped together for the participants in this study and then composite scores were created for each factor, which resulted in fewer variables in our subsequent analyses. We were not trying to determine constructs for future studies. Because data were dichotomous, a factor analysis was conducted with the tetrachoric correlation matrix (Lorenzo-Seva and Ferrando, 2012). The dimensionality was fitted using the unweighted least squares procedure and a varimax rotation. Initially, the tetrachoric correlation matrix was not positive definite. Two items that were minimally correlated to the other items were deleted (i.e. post-test items 11 and 13). Subsequently, post-test item 6 was not aligned any factor and was also eliminated from further analyses. Scree plot results suggested four factors. Structure coefficients from the remaining 19 items indicated an alignment with four factors, which we named as the following: Factor I: Immune System and HIV (7 items), Factor II: Cells and Viruses (3 items), Factor III: HIV Infection (3 items) and Factor IV: Terminology and Measurement (6 items). Composite scores were created for each factor by creating an average score.

Analysis

Student mean gains from pre- to post-test initially were explored with paired *t*-tests. Because the homogeneity of variance assumption was violated, a Kruskal–Wallis test was conducted to compare scores by grade level. We then used hierarchical linear modelling (HLM) as an additional statistical approach to account for the effects of individual teachers or environments (class-specific effects) on the differences in student scores. In other words, we were interested in the effectiveness of the instructional materials at different grade levels – independent of teacher expertise or setting. Following the step-up strategy (cf. West et al., 2015), we first fitted a means-only model for the difference scores allowing the intercept to vary by teacher (M0). We then added pre-test, grand mean centred, as a level 1 covariate, first as a fixed effect and then as a random effect (M1, M2). We then added grade level group as a level 2 covariate in M3. In the final model (M4), we added cross-level interactions between student pre-test scores and grade level group.

Table 2. Descriptive statistics disaggregated by grade and type of school.

	School type					
	Regular public		Nontraditional public		Private	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Seventh grade						
M (*SD*)	.374 (.112)	.444 (.102)				
n	47	47				
Eighth grade						
M (*SD*)	.473 (.145)	.719 (.190)	.388 (.083)	.499 (.108)		
n	97	97	33	33		
High school						
M (*SD*)	.511 (.168)	.594 (.178)	.423 (.125)	.458 (.162)	.609 (.143)	.629 (.155)
n	116	116	62	62	67	67

SD: standard deviation.

Results

Assessment gains

Overall, students demonstrated a mean gain of 9% correct answers from pre- to post-assessment, $t(430) = 10.25$, $p < .001$. When disaggregated, all student groups achieved gains in content-knowledge mean scores from pre- to post-assessment (Table 2). However, there were performance differences among school populations. Private school students began the programme with a pre-test average that was comparable to the post-test score for students enrolled in regular public schools and demonstrated minimal gains. Students enrolled in nontraditional public schools had lower mean pre-test scores than students at traditional public schools (i.e. non-magnet and non-charter public schools).

Our analysis of student data focuses on students enrolled in traditional public schools. As can be seen in Table 3, students enrolled at traditional public schools had relatively high pre-existing knowledge about the general lack of a cure for AIDS (question 2), how HIV infection leads to illness (question 4) and the immune system (questions 15 and 16). In the following order, students demonstrated greatest gains in items related to what an HIV particle looks like (question 9; in Activity 1), countries with high infection rates (question 20; in Activity 4), Karposi's Sarcoma as a rare cancer associated with AIDS (question 6; in Activity 1), differences between HIV and AIDS (question 1; in Activities 1, 2 and 3) and preventability of HIV (question 19; in Activity 5). The greatest knowledge gain overall was achieved on the assessment item related to the paper HIV virus particle that each student constructed in class (question 9). The second highest gains were seen in an item related to authentic epidemiological data used by students (question 20). All of the activities corresponded to at least one of the items with the largest gains, which provides further support for the importance of all the activities.

Grade-level analyses

We used data from the 10 non-selective, traditional public schools to examine the effectiveness of the unit for different grade levels. We excluded the two private and two nontraditional schools from this analysis for the following reasons: (a) results for the two private schools suggested ceiling

Table 3. Results for students enrolled in regular public schools ($n = 260$).

Item no.	In Activity no.	Stem	Pre-test		Post-test		Change
			M	*SD*	*M*	*SD*	
1	1,2,3	What is the difference between HIV and AIDS?	0.48	0.500	0.69	0.464	0.21
2	3,5	Is there a cure for AIDS?	0.79	0.409	0.79	0.406	0.00
3	4	Approximately how many people worldwide were living with HIV in 2009?	0.38	0.487	0.49	0.501	0.11
4	1,2	HIV can make a person ill because:	0.83	0.372	0.87	0.334	0.04
5	4,5	HIV is believed to have evolved from a similar virus found in which animal?	0.72	0.452	0.86	0.346	0.15
6	1	Which normally rare cancer is often associated with AIDS?	0.12	0.320	0.37	0.485	0.26
7	1,3	What does the abbreviation 'HIV' signify?	0.63	0.482	0.77	0.422	0.13
8	1	Which of the following is not true of viruses?	0.42	0.494	0.56	0.497	0.14
9	1	What does the HIV virus particle look like?	0.29	0.456	0.76	0.429	0.47
10	1,2,3	HIV primarily attacks which of the following?	0.62	0.486	0.75	0.434	0.13
11	2,3	What is CD4+?	0.12	0.325	0.28	0.452	0.17
12	3	Which series of numbers demonstrates exponential growth?	0.55	0.498	0.71	0.456	0.16
13	4,5	Which of the following is an example of a prevalence rate?	0.22	0.415	0.27	0.446	0.05
14	4,5	What does 'CDC' stand for?	0.66	0.474	0.67	0.470	0.01
15	5	Is any group or person immune from HIV/AIDS?	0.79	0.406	0.78	0.415	-0.01
16	1,2,3	What does the immune system do?	0.83	0.376	0.90	0.306	0.07
17	1	What is a nanometer?	0.29	0.454	0.38	0.487	0.10
18	4	What is the main job of an epidemiologist?	0.37	0.484	0.50	0.501	0.13
19	5	Which of the following statements is true?	0.48	0.500	0.67	0.471	0.19
20	4	Which country has the highest percentage of people living with HIV/AIDS?	0.12	0.325	0.38	0.487	0.27
21	1,2	Which are typical components of an HIV particle?	0.37	0.485	0.54	0.499	0.17
22	2	What are the body's chief defenders against disease?	0.31	0.464	0.49	0.501	0.18

SD: standard deviation; AIDS: acquired immune deficiency syndrome; CDC: Centers for Disease Control and Prevention.

effects for the knowledge assessment that was used, thus these results provided little insight that could be extrapolated to a general population; and (b) similarly, in the cases of the selective, non-traditional public schools, we lacked detailed information about why students performed at much lower levels than other students at both the middle and high school levels. Thus, because this information was not based on a broad cross-section of students, private and nontraditional student data were excluded from the grade-level analysis.

We compared students in grade 7, grade 8 and grades 9–12. High school data were aggregated across multiple grade levels (9–12), because most teachers taught the unit to multi-grade classes (such as biology). Results indicated that there were statistically significant differences in the medians by grade level for pre-test scores, $\chi^2(2, N=260)=25.22$, $p<.001$, and post-test scores, $\chi^2(2, N=260)=66.81$, $p<.001$.

HLM analysis

Table 4 contains pre-test, post-test and difference scores disaggregated by the 10 traditional public school teachers included in the HLM analysis. Table 5 contains the results of a successive set of HLM models analysing the differences in students' post-test and pre-test scores. Of the four models tested, M3 fit the data best, as it had the lowest Akaike information criterion (AIC).

Model 3 (M3) indicates that the average seventh grader who scored at the grand mean on the pre-test ($M=47.21$) scored 3.8% lower on the post-test than on the pre-test as opposed to eighth graders who scored 30% higher and high school students who scored 15% higher under the same conditions. On average, scoring higher on the pre-test had a negative effect (–0.62) on estimated difference scores. The correlation between the random effect for the slope and random effect for the intercept was –.78. The magnitude of this correlation suggests there is evidence of a systematic relationship between these quantities. The unexplained differences between classes are associated with unexplained differences in the effect of pre-test on difference scores such that the negative effect of pre-test on difference scores was stronger within classes that had higher levels of unexplained performance. Thus, controlling for class-specific effects, the HLM analysis indicates that on average, eighth-grade students and those who had lower levels of content knowledge prior to starting the unit had greater content-knowledge gains than similar peers in other grade levels and those with higher pre-test knowledge, respectively.

Boxplot comparisons

Boxplot comparisons in Figure 1 illustrate grade level differences across the four factors. Solid lines represent median scores, and circles represent outliers. Eighth-grade students showed the greatest content-knowledge gains after the intervention. For Factor I (the Immune System and HIV), regardless of grade level, students scored reasonably well on pre-test scores. For Factor II (Cells and Viruses), boxplots of post-test scores indicate that high school students exhibited more knowledge on pre-test scores but eighth-grade and high school students performed about equally well on post-test scores. The latter helps explain the higher gains for eighth graders because their existing knowledge on Factor II was less than high school students. However, median scores and spread of scores did not change on Factor II for seventh-grade students. For Factor III (HIV Infection), boxplot comparisons for pre-test scores indicate similar spread of data and identical median scores for eighth-grade students and high school students, but that eighth-grade students had higher gains. For seventh-grade students, the median on pre-test scores for Factor III was zero; therefore, gains were produced for some students. On Factor IV (Terminology and Measurement), post-test scores for eighth-grade students were higher and less spread out than for high school students.

Teacher perceptions

All 15 participating teachers shared their opinions about the quality and effectiveness of the unit overall, as well as each individual activity. Figure 2 provides distribution of responses. All but one teacher agreed or strongly agreed with the statement that the unit encouraged students to consider careers in health and science. The majority agreed or strongly agreed that the unit would help teachers feel more comfortable with science activities ($n=11$) and motivate children to pursue other science courses ($n=10$).

Table 4. Scores disaggregated by regular public school teachers.

Teacher	Grade	Hispanic (%)	*n*	Pre-test scores				Post-test scores				Difference scores			
				M	*SD*	95% CI for mean		*M*	*SD*	95% CI for mean		*M*	*SD*	95% CI for mean	
						Lower bound	Upper bound			Lower bound	Upper bound			Lower bound	Upper bound
A	8	22	34	0.528	0.114	0.488	0.568	0.808	0.113	0.768	0.847	0.279	0.138	0.231	0.328
B	8	13	22	0.570	0.100	0.526	0.615	0.787	0.086	0.749	0.825	0.217	0.109	0.169	0.265
C	8	74	22	0.426	0.137	0.365	0.486	0.775	0.133	0.716	0.834	0.349	0.181	0.269	0.429
D	HS	32	34	0.666	0.119	0.624	0.707	0.751	0.103	0.716	0.787	0.086	0.092	0.053	0.118
E	HS	20	15	0.561	0.173	0.465	0.657	0.661	0.136	0.585	0.736	0.100	0.259	–.043	0.243
F	HS	37.5	23	0.439	0.108	0.392	0.486	0.579	0.172	0.505	0.654	0.140	0.173	0.066	0.215
G	HS	40	18	0.402	0.091	0.356	0.447	0.482	0.134	0.416	0.549	0.081	0.134	0.014	0.147
H	7	95	47	0.374	0.112	0.341	0.407	0.444	0.101	0.414	0.474	0.070	0.135	0.030	0.109
I	HS	10	26	0.420	0.151	0.359	0.480	0.442	0.118	0.395	0.490	0.023	0.119	–.025	0.071
J	8	94	19	0.316	0.095	0.270	0.362	0.419	0.139	0.352	0.486	0.103	0.116	0.047	0.159

SD: standard deviation; CI: confidence interval; Hispanic (%): the percent of Hispanic students enrolled in the teachers' classrooms; HS: high school.
The items are ordered from highest to lowest post-test scores.

Table 5. HLM results.

	Model				
	M0	M1	M2	M3	M4
Fixed	Coeff. (*SE*)	Coeff. (*SE*)	Coeff. (*SE*)	Coeff. (*SE*)	Coeff. (*SE*)
Intercept	14.48 (3.14)	14.35 (4.10)	15.02 (3.93)	–3.79 (6.80)	–0.98 (8.18)
Pre-test		–0.69 (0.06)	–0.66 (0.10)	–0.62 (0.11)	–0.81 0(.33)
Eighth grade				29.59 (7.37)	26.24 (9.18)
High school				15.15 (7.19)	12.10 (9.00)
Pre-test: Eighth grade					0.23 (0.38)
Pre-test: High school					0.21 (0.37)
Random					
σ_e^2	207.04	134.99	127.56	126.61	126.65
σ_{u0}^2	89.21	160.72	146.08	62.43	60.57
σ_{u1}^2			0.06	0.09	0.09
σ_{u01}				−1.88	−1.80
Model fit					
Deviance	2,148.95	2,047.31	2,040.28	2,030.24	2,029.85
AIC	2,154.85	2,055.31	2,052.28	2,046.24	2,049.85

HLM: hierarchical linear modelling; AIC: Akaike information criterion.
Pre-test is grand mean centred.

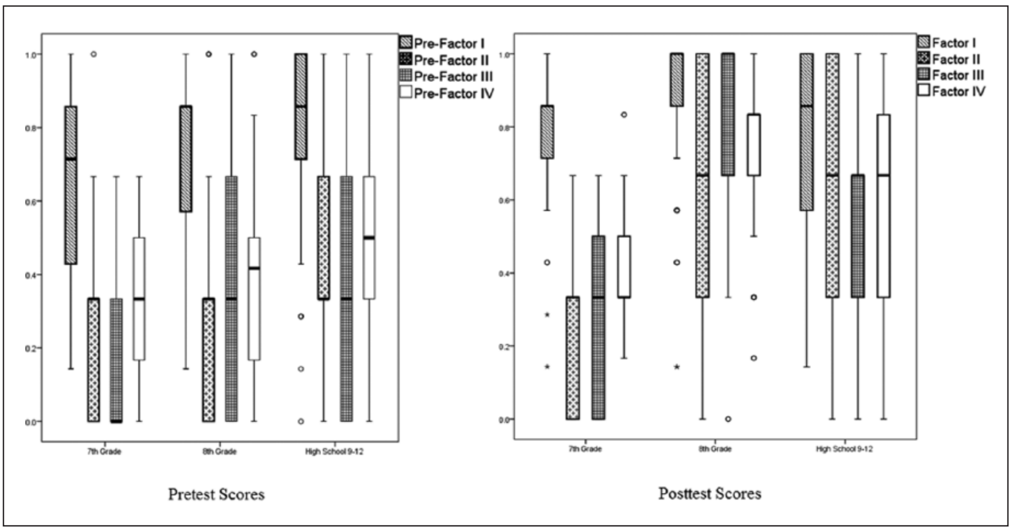

Figure 1. Boxplot comparisons of pre-test and post-test scores by grade level for regular public schools (*n* = 260).

Teachers also rated several aspects of individual activities as poor, fair, good or excellent. As seen in Figure 3, teachers consistently selected positive ratings. Activity 2, which focused on the virus' replication cycle, had slightly lower ratings than the other activities on all aspects.

Grade-level differences existed on whether the unit as a whole helped children learn science content required by the state of Texas educational standards (Texas Essential Knowledge and Skills

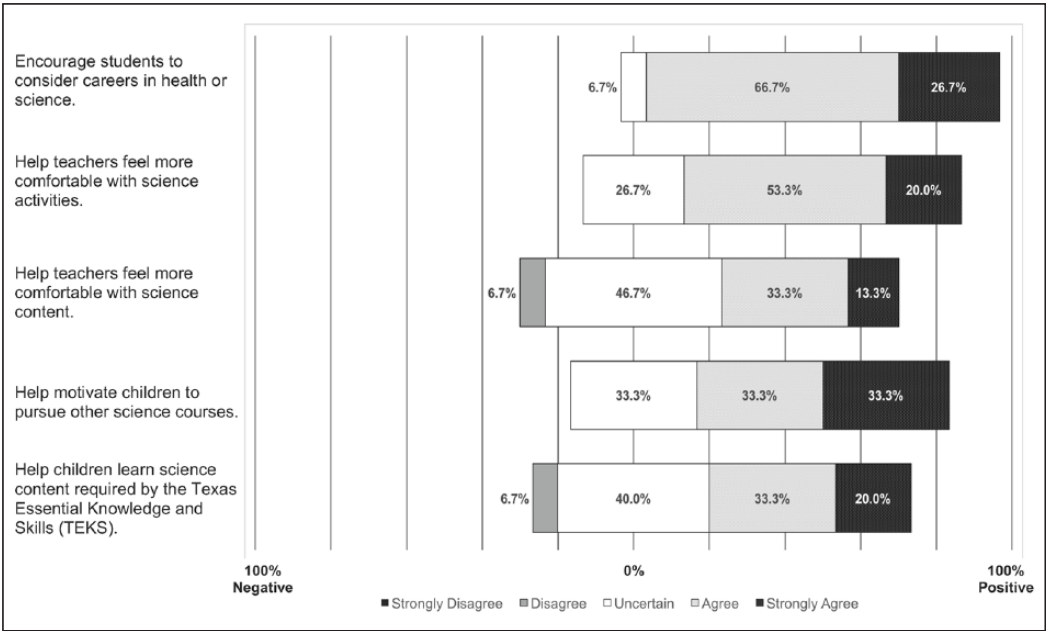

Figure 2. Percentage of teachers agreeing to each statement about the ability of the unit ($n = 15$).

[TEKS]); four of the five traditional high schools' teachers agreed with that statement, while the one seventh-grade and two of the four eighth-grade teachers were uncertain or disagreed with that statement. The sole high school teacher who answered 'uncertain' taught ninth graders and indicated that the topics would not have been covered in ninth grade. The degree of grade-level appropriateness of activities became even more apparent when comparing teachers' open-ended remarks. The seventh-grade teacher commented, 'The information was too much for seventh graders. It also is in addition to the TEKS, but good for my Pre-AP students'. One eighth-grade teacher noted that he or she needed more material throughout the day and that 'for advanced students the activities were completed with a minimal time'. A high school teacher, who did not have any students below grade level stated that he or she 'added my own methods of questioning to them in order to draw out answers and draw attention to pertinent information'.

Discussion

The Science of HIV/AIDS unit was designed to increase students' knowledge of HIV, the immune system and infection rates around the world through guided inquiry activities with related essays. Overall, the approach of providing HIV education through a focus on disease biology and epidemiology was successful in increasing students' content knowledge of HIV, its transmission and the current state of the pandemic. Although such knowledge gains were expected because the assessment was closely aligned with the curriculum, the success of this approach to HIV education in both student engagement and instructional effectiveness is encouraging. The gains indicate that delivering HIV content from this perspective can provide students with important, relevant, health information, while possibly being more acceptable to teachers and districts than traditional HIV education focused on transmission and behaviours. Furthermore, it simultaneously provides a real-world context to expand students' science knowledge and skills. Ultimately, this curriculum may

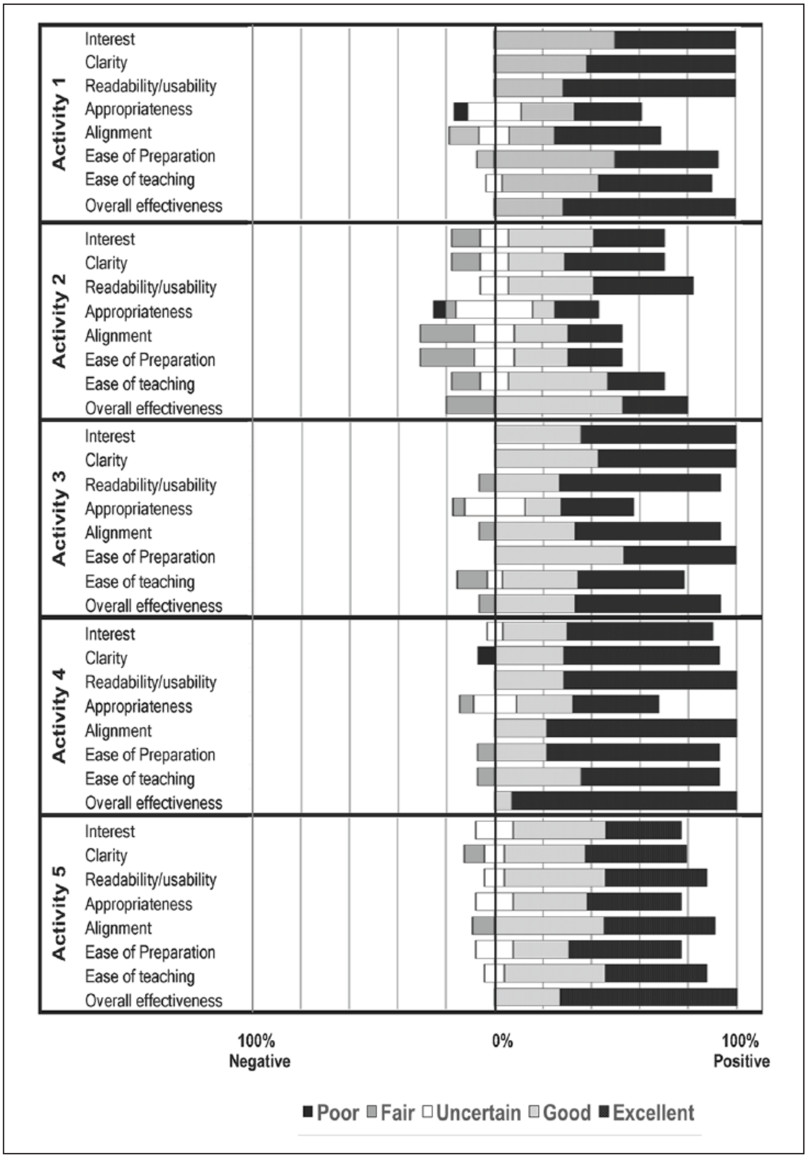

Figure 3. Percentage of teachers rating each aspect of the activities positively or negatively by answer option ($n = 15$).

provide a mechanism for filling some important knowledge gaps on a highly relevant and important issue that might otherwise be avoided altogether.

While all groups of students showed increases in content knowledge from pre- to post-test on the assessment presented in the Online Appendix, gains varied among different grade levels and school types, suggesting that the unit may have a target grade range. Specifically, the greatest knowledge gains on the assessment instrument were observed with students in grade 8. The content level appears to simply have been too high for the seventh-grade students for whom many of the life sciences concepts in the unit were new (based on teacher comments). At the other end of the spectrum, high school students likely had received instruction in some of the content prior to the field test. This seems probable given that high school teachers were much more likely to agree that the content was aligned to state standards. In addition, previous exposure to some of the cell biology concepts could have diminished engagement of high school students with the material (even if they had not mastered the content; Hoppe et al., 2004). Thus, it seems likely that eighth grade (ages 13–14) is an ideal target grade for this unit.

These results will need to be examined with other populations. However, it is significant that the unit was effective for students in grade 8, because students at this age are less likely to engage in risky sexual behaviours than high school students. Nationwide, only 6.6% of students initiated sexual intercourse before age 13 years (Kann et al., 2014). In addition, given that racial and ethnic minority populations have the highest new infection rates (CDC, 2012), the effectiveness of this unit in a diverse setting is particularly important and encouraging. Thus, providing diverse students with accurate information about transmission and disease incidence prior to becoming sexually active could have positive impacts on health (Kurth et al., 2015).

Importantly, the study also provided support for the use of active learning strategies based on real scientific problems with students. Questions that were related to classroom activities conducted by students demonstrated the greatest pre- to post-knowledge gains. These gains were related to use of a paper virus model and extensive use of CDC data regarding HIV infection rates worldwide. Teachers' responses to Likert-type scale and open-ended items also suggested that the activities related to population-level data were engaging to students and helped develop their skills in this area. Finally, no teachers reported barriers to implementing the lessons, suggesting that these can be reasonably implemented in science classrooms.

Limitations

Although, in terms of content, the unit seems to be most suited to and beneficial to the eighth-grade population, the small, unrepresentative sample size, especially for seventh graders who were all taught by the same teacher, makes generalisation beyond the study context difficult. Future studies should include a combination of middle and high schools that are both urban and suburban in nature, ideally across a range of classrooms, as the volunteer nature of recruitment on a sensitive subject may indicate that the abilities of the participating teachers to navigate the content are not generalisable to their peers who did not volunteer. Also, in the USA, the curriculum for each grade varies by state, so grade-specific objectives in any particular state should be taken into account before generalising grade-level outcomes outside of our study participants. Finally, in order to have an understanding of the overall effects of this type of instruction, future studies may want to investigate the impact of this context-based virology and epidemiology unit on students' overall academic outcomes. The differences in knowledge pre-tests among students attending private and public schools also is an area that warrants further exploration, in the light of ongoing discussions about the importance of equitable access to high-quality curricula and teaching in all subject areas (Darling-Hammond, 2010).

Conclusion

Implementation of the new HIV-related science curriculum in this study led to student content-knowledge gains about viral biology, HIV, population data and exponential growth, and the AIDS pandemic. These gains were observed among students in grades 7, 8 and 9–12. Based on gains scores among students enrolled in public schools and teachers' observations, the best target grade level for the unit is grade 8. Teachers' observations of students suggest that while the content portion of the curriculum may not have been optimal for all students, the engaging nature of the materials was helpful in increasing students' health and science literacy for all ages. Furthermore, science activities based on real-world health topics promoted the development of these students' topic-related content knowledge and provided an opportunity for the development of science, technology, engineering and mathematics (STEM) skills, such as analysing geographic data. Results indicate that, in general, these materials have the potential to provide timely, relevant information to diverse student populations who do not have consistent quality access to HIV information, and in doing so strengthen content-knowledge science skills and health literacy.

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Note

1. In the US educational system, middle school typically refers to grade 6 (ages 11–12), grade 7 (ages 12–13) and grade 8 (ages 13–14), while high school refers to grade 9 (ages 14–15), grade 10 (ages 15–16), grade 11 (ages 16–17) and grade 12 (ages 17–18). While students in middle school are taught science by grade level, students in the four high school grades have some flexibility and are able to take elective and honours courses. This results in a combination of grade levels and ages in different high school science courses.

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