RESEARCH ON LEARNING

The Impact of Using Geographic Information Systems Technology on Students' Understanding of Epidemiology

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Abstract

To enhance/update our microbiology course, we employed a geographic information science and technology (GIST) infusion to improve students' understanding of epidemiology and disease spread and to encourage students to earn a GIST certificate, making them more marketable in an increasingly competitive workplace. Following a 25-minute introductory GIST infusion lecture during a microbiology class session, a 1.5-hour GIST laboratory exercise was performed in which teams of students evaluated Centers for Disease Control (CDC) chlamydial disease incidence data. In addition to answering three quiz questions addressing the data, students created a map, using ArcGIS software, indicating which Texas counties experienced the highest rates of chlamydia in 2014. To determine the efficacy/value of our infusion, GIST survey data (pre- and post-infusion), GIST lab quiz scores, and answers to four GIST lecture exam questions were evaluated. In conclusion, our study was successful in improving understanding of what GIST is and how it could impact biological fields by improving attitudes about the likelihood of further GIST study leading to a certificate program, and by exposing biology undergraduates to GIST technologies and software, enabling student data mapping. Ultimately, our efforts could promote enhanced vocationalization of our biology program, thereby enhancing and broadening employment opportunities for our graduates.

Key Words: *curricular enhancement; professional development; student preparation; surveys; environmental sciences; geospatial information science and technology (GIST); GIST infusion.*

○ Introduction

The broadly interdisciplinary geographic information science and technology (GIST) field integrates hardware, software, and data for capturing, managing, analyzing, and displaying within a geographic, spatial, and temporal context (Goodchild, 2006; NRC, 2010; Jensen & Jensen, 2012). Geospatial technology has become integral to decision making in geology, environmental science, ecology, civil engineering, transportation, urban planning, business, and health care (NRC, 2013; Jensen & Jensen, 2012). It is also projected to become one of the nation's largest growth industries (USDOL, 2005; NRC, 2013). Recently, the Bureau of Labor Statistics reported that the employment opportunities in GIST fields are expected to grow faster, at 29 percent, than the national average rate (13%) of all other occupations (BLS, 2014). Hence, competency in the field of geospatial science will enhance Texas Southern University's (TSU) undergraduate students with additional career opportunities while improving both their research and academic skills.

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An earlier article (Baker et al., 2015) carefully articulated the need for enhanced GIST involvement in the classroom across all levels of education. In adopting that philosophy, we sought a problem/project-based learning (PBL) approach, since PBL has been a pedagogical modality used in higher education biology (Ward et al., 2014; Zimbardi et al., 2013; Lepiller et al., 2017; Ogilvie & Ribbens, 2016). Many medical schools have similarly adopted a PBL approach when training aspiring physicians (Lepiller et al., 2017). When coupled with the more traditional didactic modality (Epstein, 2004), PBL has proven to be a highly effective pedagogical adjuvant. Recognizing that the biological sciences have been increasingly influenced by rapidly emerging biotechnologies over the past ten years, but that curriculums typically lag behind in adequately exposing students to these emerging technologies, we sought to address that deficiency head-on. Previously, we sought to update the microbiology teaching laboratory through the infusion of molecular biology, whereby students identified unknown bacterial isolates form their homes using the polymerase chain reaction following DNA extraction of each of the purified isolates. Amplified regions of DNA were highly conserved (encoding

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16S RNA), allowing for identification through comparisons with published sequences available in various databases (Rosenzweig & Jejelowo, 2011).

In this current effort, we sought to infuse the microbiology course curriculum with GIST in a manner proposed by Baker et al. (2015). GIST can be broadly employed as a tool in all STEM disciplines and beyond. In our PBL-like approach, undergraduate biology (STEM) students (N = 64) were exposed to a two-pronged GIST infusion. The first phase of GIST infusion involved a 25-minute didactic introductory GIST lecture; the second infusion wave took place several weeks later and involved a laboratory project in which teams of students mapped disease incidence data using GIST software. This approach enabled us to expose biology students to a readily usable GIST tool easily adoptable in all STEM fields. Ultimately, our pilot experiment will enable us to eventually develop a GIST certificate program, which has the capacity to greatly enhance a large number of underrepresented minority STEM students' employment options (Jones et al., 2010). Our efforts will support the finding that undergraduate research experiences support a science career decision (Villarejo et al., 2008; Russell et al., 2007; Lopatto et al., 2007).

○ Research Design and Methodology

Survey Driven Data

As mentioned above, to assess our students' initial understanding of GIST and their attitudes toward pursuing advanced GIST training through an eventual GIST certificate program, we developed an attitude GIST survey that was administered to the class ahead of the 25-minute instructional GIST infusion lecture. At the conclusion of the GIST infusion lecture, the same survey tool was again distributed to assess whether the delivery of the GIST infusion lecture was both informative and effective in positively enhancing student attitudes toward advanced GIST study.

Materials Needed

The objective of this GIST infusion exercise is to infuse the geospatial science concepts into the existing biology undergraduate curriculum. The infusion of geospatial sciences will establish a strong interdisciplinary research base and bring awareness for quantitative, spatial research for biology students. GIST software such as ESRI ArcGIS integrates common database operations such as map querying and statistical analysis. It allows dynamic displays by linking the databases with maps; this is not possible with traditional data analysis. Open-source software such as Quantum GIS can also be used. Apart from human diseases, GIST also has wider applications for mapping the spread of invasive plant species, wildlife habitat, population trends, cropping patterns, forest management, and landscape changes.

For this GIST infusion, instructors looking to adopt this approach will require access to several key software programs, such as ArcGIS 10.3 (ESRI Inc.). Depending upon what biological/health data the instructor wants to map, he/she will require access to public databases (e.g., national, state, county, city). For example, for plotting our chlamydial disease incidence data from Texas in 2014, we used the Centers for Disease Control (CDC) public database (https://gis.cdc.gov/GRASP/NCHHSTPAtlas/main.html). We would strongly suggest that instructors at a community college or high school seek out an active collaboration with a nearby institution that employs GIST for its fields of study, and not become discouraged in thinking that they will have to purchase cost-limiting software programs.

Concept Explanation

As alluded to earlier, three weeks after a 25-minute introductory GIST infusion lecture is delivered (and pre-/post-infusion surveys are collected), students are teamed up during a 1.5-hour GIST laboratory. For students (19) who did not attend class the day the GIST infusion lecture was given, the lecture notes (PowerPoint slides) were posted on blackboard for all students to access. Prior to the GIST laboratory, a GIST teaching assistant demonstrated how to utilize the various statistical software: GIST software (ESRI ArcGIS 10.3), remote sensing software (ERDAS Imagine and ERMapper), Microsoft Excel and statistical software for data analysis, and Microsoft Power Point for preparing presentations and posters. Students also acquired training in accessing the open-resource databases and in data safety. We, and others, previously demonstrated that such near-peer tutoring, under the auspice of a vertically aligned educational opportunity, is highly effective (Singh et al., 2014; Ross et al., 2015; Smith et al., 2015; Wijnen-Meijer et al., 2010; Rosenzweig et al., 2016).

During the GIST lab, teams were required to plot CDC-derived chlamydial disease incidence data from Texas in 2014 and determine which Texas counties have the (1) highest, (2) lowest, and (3) highest and lowest incidence rates per 100,000 individuals). These three points served as quiz questions for the lab period. In addition to answering the quiz questions, students were also required to produce several PowerPoint slides mapping the incidence data for the state, to demonstrate their skills acquired.

Measurable Outcome

The measurable outcomes derived from our infusion effort were: (1) GIST lab quiz scores, (2) production of GIST maps for chlamydial disease incidence in Texas (2014), and (3) performance on the four GIST exam questions assessing the GIST lecture infusion (see Table 2).

○ Results and Discussion

Student Survey Data

As part of GIST infusion effort, we wanted to determine the baseline knowledge and attitudes toward GIST of our 45 representative STEM (biology) students' in attendance that day, and whether our infusion efforts could improve their understanding and attitudes toward advanced study in GIST courses. To achieve this, we developed a five-question survey instrument which included the five questions listed in Table 1.

Not surprisingly, prior to our 25-minute introductory GIST infusion lecture, 70% of total students polled responded that they were not aware of GIST (Q1), while only 16% and 14% responded that they were aware or were unsure, respectively (Fig. 1A). In sharp contrast, following our infusion, awareness about GIST (Q1) was changed dramatically. More specifically, 100% of all respondents confirmed that they were aware of what GIS is (Fig. 1B). Similarly, prior to infusion, only 11% of participants thought they used GIST in day-to-day life (Q2), while the majority of students were either unsure (50%) or believed that they did not use GIS daily (39%) (Fig. 1A). However, following GIST infusion, 96% of participants

Table 1. Survey question instrument developed to assess students' baseline knowledge and attitudes toward GIST.

Q1	Are you aware of geographic information systems (GIST)?
Q2	Do you use GIST data in your day-to-day life?
Q3	Do you think GIS has any applications in your field of study?
Q4	Would you be interested in learning GIST?
Q5	Do you think learning GIST will improve your job opportunities, knowledge, and skills?

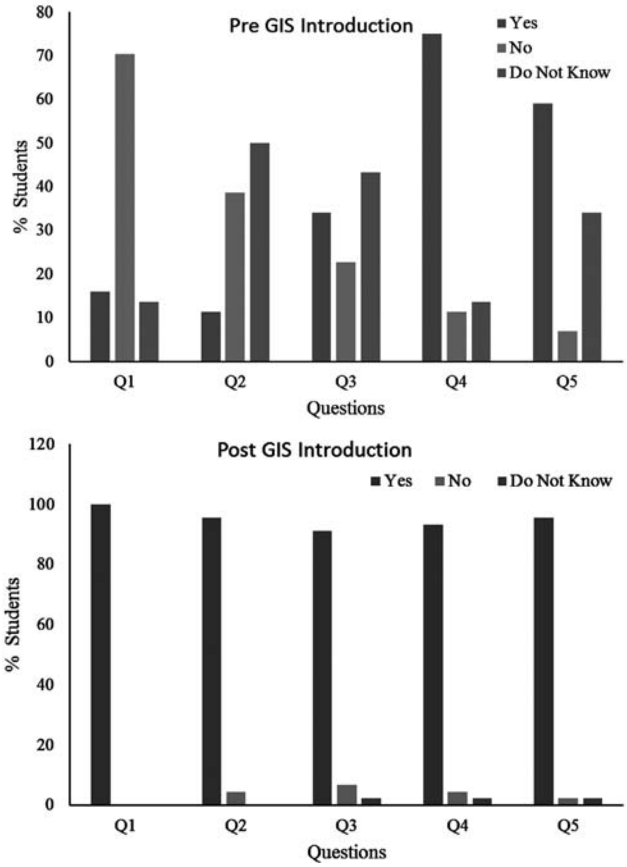

Figure 1. GIST survey data of 45 undergraduate microbiology students pre- and post-GIST infusion lecture. (See Table 1 for the list of survey questions used.)

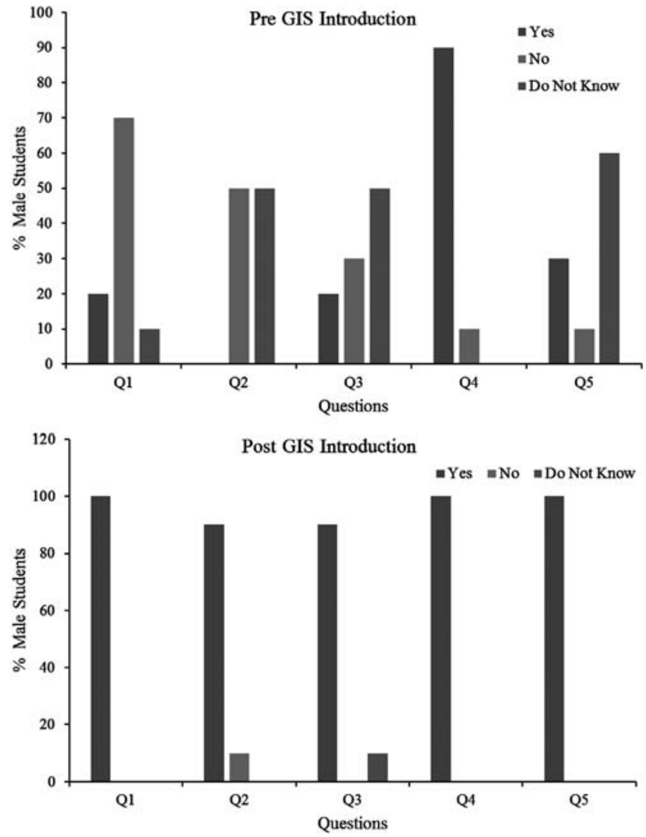

Figure 2. GIST survey data of 10 male undergraduate microbiology students pre- and post-GIST infusion lecture.

understood that they use GIS daily, while only 4% of students maintained they did not (Fig. 1B). Additionally, following our GIST infusion, the number of students who believed that GIS could be employed in biology (Q3) increased from 34% to 91% (Fig. 1), while the number of students who believed GIS could not be employed in biology decreased from 23% to 7% (Fig. 1).

More importantly to us, following GIST infusion, the number of students who expressed an interest in learning more about GIS (Q4) increased from 75% to 93%, while the number of students uninterested in further GIS student decreased from 11% to 4% (Fig. 1). Similarly, when asked whether they believed that GIS knowledge could enhance their job opportunities and skills in biology fields, the number of students in agreement increased from 59% to 96% following the GIST infusion (Fig. 1). Further, the number of students who were unsure decreased from 34% to 2% following our GIST infusion (Fig. 1).

In addition to assessing the students as a whole (N = 45), we also sought to determine whether there were any glaring differences between the class female (n = 35) and male (n = 10) subpopulation survey data. For the male students, "yes" answers for Q1, Q2, Q3, Q4, and Q5, respectively, increased: 20% to 100%, 0% to 90%, 20% to 90%, 90% to 100%, and 30% to 100% (Fig. 2). Similarly, for female students, "yes" answers also increased: 15% to 100%, 15% to 97%, 38% to 91%, 71% to 91%, and 68% to 94% (Fig. 3). There was one striking difference with regard to pre-infusion "yes" answers to Q5 between females and males, though. Even before our GIS infusion, 68% of female students believed that learning GIS would improve their employment opportunities, (Fig. 3) compared to only 30% of males.

The pre- and post-survey responses of the students were statistically tested by the simple non-parametric Wilcoxon-Mann-Whitney test using the MINITAB 17 (MINITAB Inc.) software. The post-survey responses to all the questions were statistically significant ($p < 0.05$) compared to the pre-survey responses in case of both the male (Fig. 2) and female (Fig. 3) students, indicating a significant increase in awareness about GIS among the students following the lecture session. No significant differences between the male and female responses were observed for both the pre- and post-survey data, indicating that the survey results are

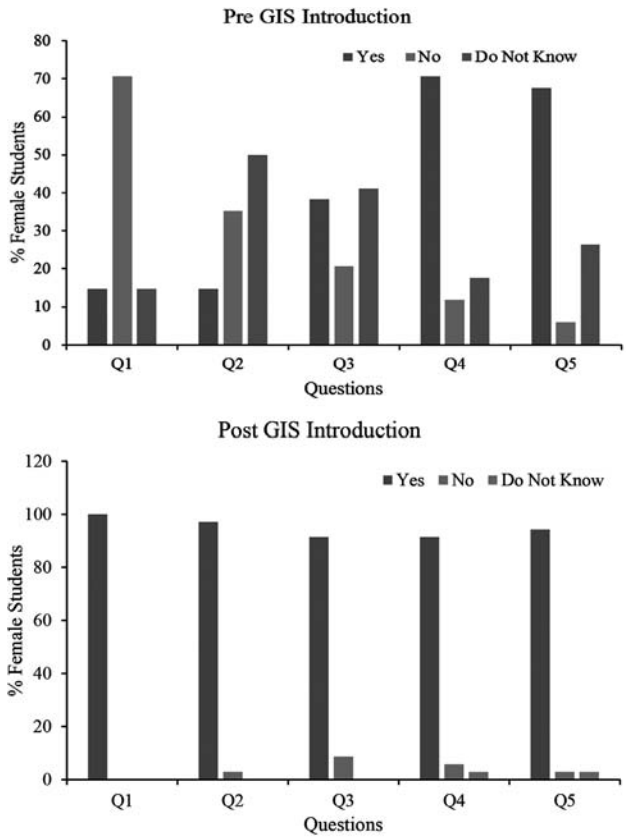

Figure 3. GIST survey data of 35 female undergraduate microbiology students (A) pre- and (B) post-GIST infusion lecture.

gender-independent. Taken together, our survey data suggest that our pilot infusion effort was capable of improving student understanding of GIS and increased the likelihood of recruiting undergraduate biology students into a future GIS certificate program.

Exam Questions Data

To determine whether mastery of GIST knowledge was achieved, a lecture exam was administered about three weeks following the GIST infusion lecture; it covered seven chapters and included four questions assessing knowledge regarding GIST and its applications (Table 2). Unfortunately, the number of test takers (N = 64) exceeded the number of survey participants (N = 45), indicating that 19 students who took the exam were not present for the GIST infusion lecture. However, these students also had access to the GIST lecture notes (PowerPoint slides) on blackboard.

With regard to question 1, 48% of all students (N = 64) got it correct. However, when comparing the performance of male (n = 16) to female (n = 48) students for question 1, it is clear that male students (for reasons unclear) had a better understanding of what GIS stands for as an acronym (75% vs. 40%, respectively; Table 2). However, the performance of both male and female students on questions 2, 3, and 4 closely mirrored their composite performance when asked about what GIS does not do, who uses GIS, and spread of what microbial disease was mapped using GIS during our infusion (~65%, ~92%, and ~39% correct answers, respectively; Table 2). Students likely chose the wrong answers more frequently for questions 1, 2, and 4 on account of some tricky wording used in the answer choices (that could be missed if not read carefully).

Taken together, it appears that additional GIST infusion lectures or an extended GIST lecture could better benefit our biology

Table 2. Performance on four GIST lecture exam questions assessing the GIST infusion within the microbiology lecture. Correct answers are in bold.

	% Males correct answer (n = 16)	% Females correct answer (n = 48)	% Total students correct answer (N = 64)
Question 1			
What Does GIST stand for? (A) graphical institutional standard (B) geospatial international standard (C) generic infrared streaming (D) geospatial information systems (E) **none of the above**	75 %	40 %	48 %
Question 2			
Which is not true about GIST? (A) GIST gathers data (B) GIST manages data (C) GIST displays data (D) **GIST creates data**	69 %	63 %	66 %

Table 2. Continued

	% Males correct answer (*n* = 16)	% Females correct answer (*n* = 48)	% Total students correct answer (*N* = 64)
Question 3			
Who uses GIST? (A) governments (B) medical fields (C) advertising (D) environmental scientist (E) **all of the above**	88 %	96 %	94 %
Question 4			
Using GIST, the spread of what microbial disease was discussed in class? (A) syphilis (B) tuberculosis (C) gonorrhea (D) herpes (E) **none of the above**	38 %	40 %	39 %

students' understanding of what GIST is and its applications. Further, we recognized that there was a significant time lapse (about 3 weeks) from when the GIST infusion occurred within the classroom until the lecture exam was given. During that span, students were presented with a rather large and broad spectrum of microbiology lecture material topics that they were responsible for on the exam (i.e., eukaryotic pathogens, viruses [of bacteria and animals], and host microbe interactions, in addition to material presented ahead of the infusion). Moreover, our GIST lab activity occurred after the lecture exam was administered. Collectively, these factors likely contributed to the poor performance on three of the four GIST exam questions. To improve upon this, both the GIST infusion and lab activity could be scheduled closer to the exam date to achieve an enhanced learning outcome based on exam score performances.

GIST Lab Activity Data

Beyond classroom surveys, didactic lecture infusions, and exam questions, we sought to infuse GIST into the microbiology using a PBL approach in which, using ESRI ArcGIS 10.3 software, teams plotted CDC-derived chlamydial disease incidence data from Texas in 2014 to determine which Texas counties had the (1) highest, (2) lowest, and (3) highest and lowest incidence rates per 100,000 individuals, and (4) to create a GIST plot for questions 1 and 2. The aforementioned four points served as quiz questions for the lab period. Additionally, there was an analytical bonus question inquiring why differences may exist between the raw incidence data and normalized rates. Of the 49 students participating in the GIST lab, the average score for the four-question quiz was 93% (data not shown). Most importantly, students demonstrated GIST competency by utilizing the aforementioned software programs to plot CDC-derived chlamydial incidence rate date for Texas in 2014. After GIST plotting, Harris, Bexar, and Dallas counties were identified as having the highest chlamydia incidence rates in 2014 (Fig. 4). Students also determined that the highest incidences occurred in the most heavily populated counties, those containing the cities of Houston, San Antonio, and Dallas, respectively. In completing this PBL infusion activity, students were employing the GIS skills they gained to study relevant microbiology and epidemiology data (Fig. 5).

Student Instruction and Assessment

As described above, students experienced a two-part GIST infusion in an undergraduate microbiology course. The first infusion component involved completing pre- and post-infusion GIST surveys immediately before and after a 25-minute GIST introductory lecture. The measurable outcomes for the first GIST infusion component included survey data and student performances on four GIST exam questions (Table 2).

The second component of the GIST infusion involved students engaging in a hands-on PBL GIST project. Following a GIST software demonstration by a GIST teaching assistant, student teams applied what was learned in both GIST components to the successful GIST mapping of CDC-derived chlamydial infection rate data for the Texas in 2014. The measurable outcome for the second GIST-infusion component was determined by employing a four-question quiz (which included a question on mapping the data using the GIST software).

Teacher Implementation/Suggestions

Through this NSF-funded project, undergraduate biology students were exposed to a GIST infusion in a microbiology course and will be the subject of recruitment into additional GIS courses (that could

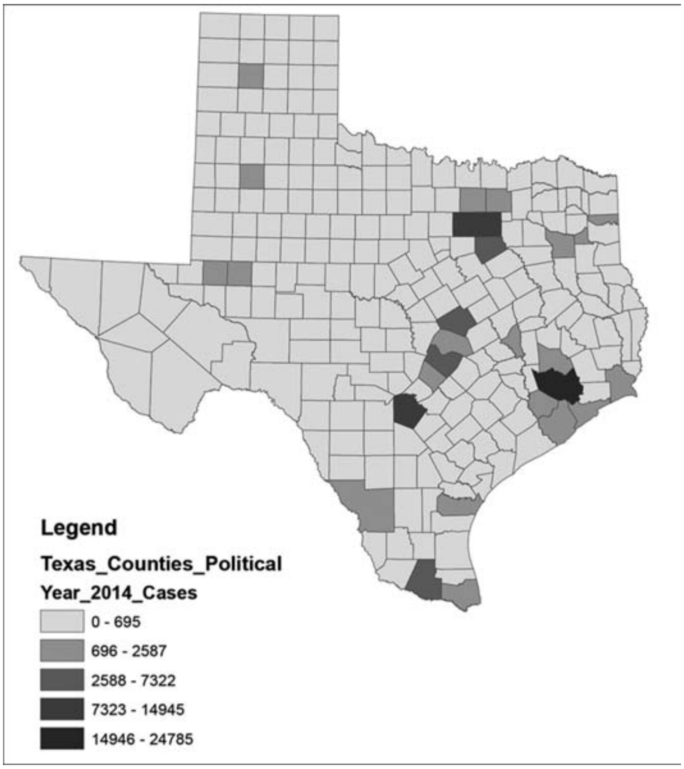

Figure 4. Student GIST map of Texas counties reporting chlamydial infections in 2014. The darker the color, the greater the number of cases.

Figure 5. On display are pictures of a team of microbiology undergraduate students at Texas Southern University using the GIST lab (and GIST software) to map Texas counties reporting chlamydial infections in 2014 as part of GIST PBL infusion project.

lead to an eventual GIS certificate). Our infusion participants received instruction and hands-on experience in downloading analytical data, downloading and processing GIS data, and integrating and analyzing geospatial data with analytical data. However, we did experience some difficulties in ensuring that all students ($N = 64$) be in attendance during the GIST lecture infusion. Attendance is essential during both phases of the infusion, and we would recommend that teachers/instructors looking to implement this (or any other) infusion incentivize students to ensure full attendance. In so doing, the instructor will be better able to correlate the information gleaned from the second infusion component with that of the first. Further, performance on the GIS exam questions would also likely be improved if all students were in attendance during the first GIST infusion component. Finally, we suggest that community college and high school biology instructors not shy away from such efforts for fear that key software is unavailable to them. We would strongly suggest that such instructors collaborate with neighboring institutions equipped with the aforementioned GIST software and expertise to better benefit their students through such a cutting-edge PBL infusion.

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