INNOVATION, IMPLEMENTATION, IMPROVEMENT OPEN ACCESS

Implementing a Secondary Database as a Teaching Tool to Improve Genomic Literacy Among Dental Students

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ABSTRACT

Background: Recent advancements in precision medicine and precision dentistry have necessitated genomic literacy in healthcare professionals. Both the knowledge of genetics and data in primary biological databases are rapidly expanding beyond what is presented in textbooks. Dental students are often unfamiliar with the growing field of biological data and the tools used to analyse and interpret genetic information.

Approach: To improve genomic literacy among dental students, we incorporated 'Bioinformatics for Dentistry', a dental-specific secondary database, as a teaching tool in the first year of the Doctor of Dental Surgery (DDS) program. This study aims to explore students' perspectives on using a secondary database as a tool for teaching and learning.

Evaluation: A convergent, parallel mixed-method study was conducted to explore student perception of the database as a teaching tool. Qualitative and quantitative data were collected from students' reflection assignments and surveys. Descriptive statistics and manifest content analysis were applied to analyse the survey data and reflection assignments, respectively. All (100%) students ($n=32$) completed the assignment with reflective answers; 38% ($n=12$) of the class completed the voluntary survey. Survey participants indicated that 'Bioinformatics for Dentistry' was easy to navigate and helpful for learning the genetics of tooth development. Codes from qualitative data were grouped into three categories, representing the benefit of the secondary database attributed by the students.

Implications: Dental students positively valued the use of 'Bioinformatics for Dentistry' to learn the genetics of tooth development. This secondary database can improve genomic literacy to meet the challenge of the postgenomic era.

1 | Background

With the increased application of bioinformatics in healthcare and the emergence of dental informatics and precision dentistry, the need for genomic literacy in healthcare professionals is rapidly growing [1–3]. Bioinformatics is the field of science that combines biology and information technology to focus on analysing large sets of biological data stored in databases [4]. Personalised genomic medicine and precision dentistry are examples of the application of bioinformatics in healthcare.

The importance of human genetics in dental curricula is well recognised [5]. At the University of Alberta, in the Doctor of Dental Surgery (DDS) program, students study basic molecular genetics, Mendelian principles of heredity, genetics of tooth and facial development, genetics of oral health, hereditary tooth disorders and genetic regulation of developmental

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anomalies. Students learn information about genes and their regulation that are not easily retained. In recent years, the knowledge of genetics and accumulated genetic data has expanded beyond what is presented in textbooks. DDS students are not equipped to use biological databases or the tools to analyse these genetic data.

> *"Students learn information about genes and their regulation that are not easily retained."*

A deep understanding of the genetic regulation of tooth and facial development is critical to dental education [5]. However, reports on initiatives to improve genomic literacy in dental students are scarce. Biological databases specific to dental genomics are also rare.

2 | Approach

We curated a dental-specific secondary database called 'Bioinformatics for Dentistry' that archives the genomic and proteomic data related to tooth development (https://dentalbioinformatics.com/) [6]. This database was introduced to the first year (DDS-I) DDS students to supplement their didactic lectures on tooth development and developmental anomalies. Two mandatory lab sessions were designed for students with hands-on activities with 'Bioinformatics for Dentistry' (Figure 1). The theoretical framework for this study is supported by Bauman's layered learning model, which describes a format of scaffolding traditional didactic teaching in combination with technology [7, 8]. Our research question is:

What are dental students' perceptions of using 'Bioinformatics for Dentistry', a secondary database, as a teaching and learning tool?

> *"Two mandatory lab sessions were designed for students with hands-on activities with 'Bioinformatics for Dentistry' (Figure 1)."*

3 | Evaluation

3.1 | Study Design and Population

A convergent, parallel mixed-method study [9] was conducted. Students' responses to a survey and reflective questions were concurrently collected and analysed to address the research question. The survey questions were developed by the authors, following the System Usability Scale (SUS) [10] and were not validated (Appendix A). The study design was approved by the University of Alberta Research Ethics Board (ID-Pro00107559). The DDS-I cohort participating in database-infused lab activities in the Winter 2024 semester was automatically enrolled in the reflective responses portion

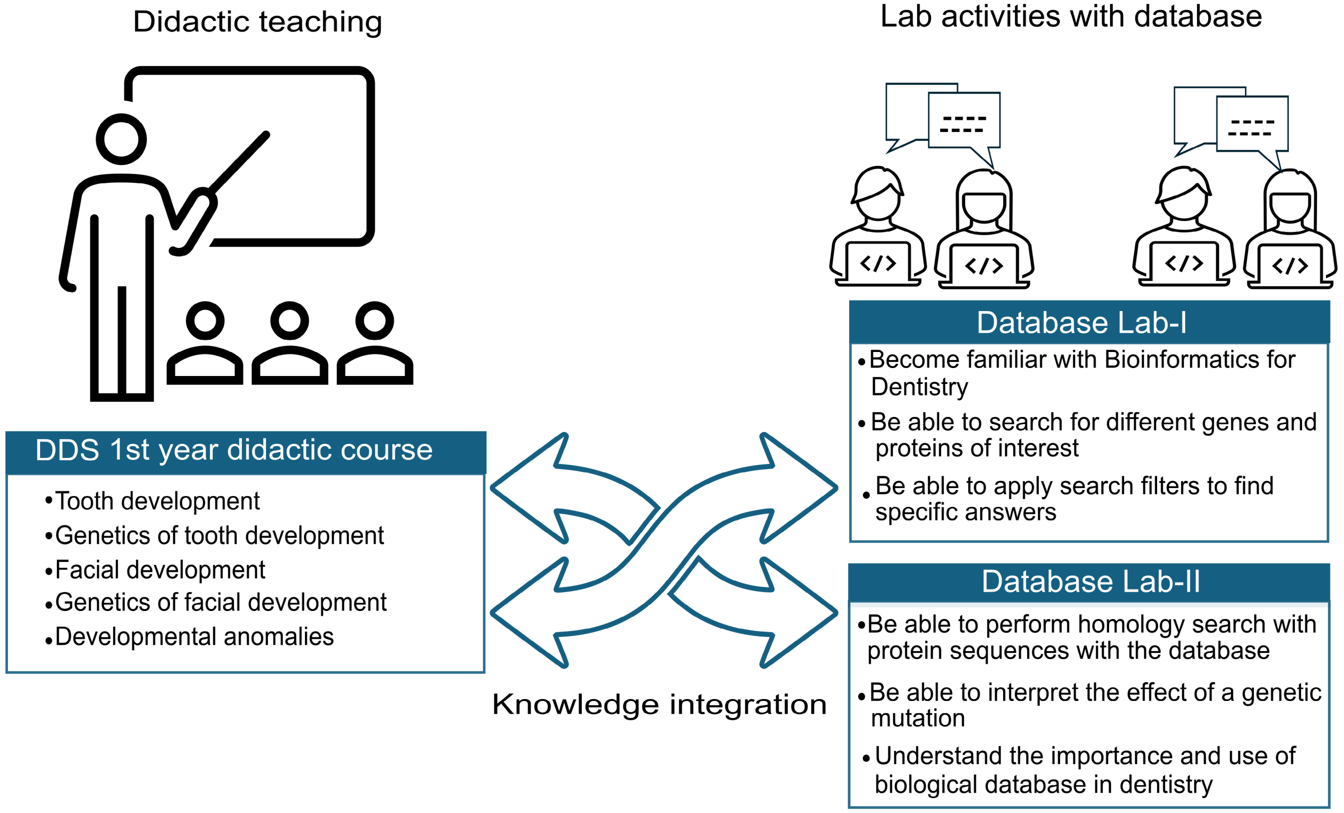

FIGURE 1 | Incorporation of 'Bioinformatics for Dentistry', a secondary database as a teaching tool. Genetics is taught through didactic lectures in first year of the DDS program. Bioinformatics for Dentistry was introduced to the students through two lab activities supplementary to the content taught in the course. This figure represents the learning outcomes and knowledge integration between the didactic lectures and the database-infused lab activities.

of the study and were also invited to voluntarily participate in the survey.

3.2 | Data Collection

In the lab activity, besides regular questions, students were asked to provide written responses to three reflective questions, asking for their opinions and experiences on (i) the use of a biological database in the field of dentistry, (ii) the use of Bioinformatics for Dentistry as a supplementary tool to learn genetics of tooth development and developmental anomalies, (iii) and what was learned using the database that was not learned from the lecture. After the lab session, students were invited to participate in the survey.

3.3 | Data Analysis

Using Microsoft Excel, descriptive statistics (e.g., percentages) were applied to analyse the survey data. Manifest content analysis, a multiple-step process for summarising views and perceptions using categories and subcategories, was used to analyse students' responses to the reflective questions [11]. Anonymised text responses were imported into Microsoft Excel and read repeatedly by both authors independently to increase familiarity with the data. 'Meaning units' were identified and coded by both authors independently. Uncertainty in identifying meaning units was resolved upon discussion. In the next step, codes were grouped into subcategories and categories, which the authors established upon discussion.

3.4 | Results

Thirty-eight per cent ($n=12$) of the class completed the voluntary survey. All (100%) students ($n=32$) completed the reflective assignment after the labs. All students answered all three questions for a total of 96 meaning units. Each meaning unit may have multiple codes. Thirty-three codes were sorted into six subcategories, which were further condensed into three categories: (i) enhance learning and knowledge, (ii) clinical practice and application and (iii) accessibility and ease of use. This third category of 'Accessibility and ease of use' is overarching and encompasses other categories (Table 1).

Survey participants either strongly agreed (83%) or agreed (17%) that Bioinformatics for Dentistry was easy to use and navigate. All survey participants either strongly agreed (67%) or agreed (33%) that they found the database helpful for learning the genetics of tooth development. Most (92%) participants affirmed that the database made learning genetics easier. 83% of the participants admitted that the database positively impacted their learning (Figure 2).

> *"Most (92%) participants affirmed that the database made learning genetics easier."*

Seventy-nine meaning units from students' reflection assignments were included in the 'Enhanced Learning and Knowledge' category. This category included the use of the database as a supplement to classroom learning, as well as how the use of the database led to a deeper understanding and appreciation of the complexity of tooth development. The results highlighted how students used the database in various ways in their learning, with 23 instances of the code 'Understanding' in the meaning units. 'Knowledge extension' also features prominently in the meaning units, with 15 instances coded. Students stressed that the database was valuable in helping them understand the scope and complexity of the mechanisms that underlie the tooth development process (Table 1).

Besides learning about the genetics of tooth development, students valued the database as an important resource for clinical practice. Thirty-seven meaning units included the mention of 'Clinical Practice and Application' of the database. This category includes student mention of the database as a way to help them conceptualise and apply their knowledge. The results revealed how students think the database is relevant to their future careers as clinicians. Thirteen meaning units were coded with 'clinical practice', and 11 meaning units mentioned that students thought the database would be useful for diagnosis. An additional nine meaning units were coded with 'communication', indicating the students felt that using the database could help their future clinician-selves more effectively communicate with other health professionals and their patients (Table 1).

> *"The results revealed how students think the database is relevant to their future careers as clinicians."*

Students also appreciate the database as an up-to-date, readily accessible source of information. Thirty-six meaning units from students' reflection assignment mentioned 'Accessibility and/or Ease of Use', which was classified as an overarching category. The meaning units showed that the students appreciate the database as a readily accessible source of information compiled specifically for oral health conditions and does not require them to memorise the function of each gene/protein (Table 1).

4 | Implications

Biological databases and bioinformatic tools have been used to improve genomic literacy in botany [12], entomology [13], biochemistry [14] and medical genetics [15]. However, databases as a teaching and learning tool in dental education have not been reported. We incorporated 'Bioinformatics for Dentistry', a dental-specific secondary database, as a teaching tool to supplement didactic teaching for DDS students.

Ease of use is essential for any teaching and learning tool. The survey results showed overwhelming agreement from students that the secondary database, Bioinformatics for Dentistry, was easy to use and navigate. Students also appreciated the organisation of data on the website and valued the positive impact of the organised, readily available data source in their learning. This result is expected, as primary databases, with extensive datasets, are usually complex in structure and difficult to navigate. When the primary database OMIM was used as a teaching modality for medical genetics, 41% of the students

TABLE 1 | Student perception of using Bioinformatics for Dentistry. In the lab activity, students were asked to provide written responses to three reflective questions (details are in the main text). All students ($n = 32$, 100% of DDS-I) answered all three questions in the assignment. Manifest content analysis was used to analyse the qualitative data from student assignments.

	Accessibility and ease of use (36 meaning units)					
Category	**Enhance learning and knowledge (79 meaning units)**		**Clinical practice and application (37 meaning units)**			
Subcategory	**Supplement to lectures/studying, reinforcement and clarification**	**Deeper understanding and appreciation of complexity**	**Conceptualisation and application**	**Connection to practice**	**Future reference**	**Accessibility and ease of use**
Representative Quotes	'... databases have extensive aggregations of knowledge and studies conducted globally for anyone to access, so one can have a high level of confidence in what they are using to learn. Furthermore, a database provides access to many different genetic aspects of tooth development and anomalies that may not be covered extensively in any particular healthcare program ...' **(Participant 26)**	'... it allowed me to see the intricate nature of tooth development and developmental anomalies. By using the database and seeing how many proteins are involved in tooth development sheds light on the complex process of tooth development and how well timed and coordinated all of the process need to be in order to have a full set of teeth. I think the lectures describe the major processes that occur but the database exercises outline how complex of a process this truly is.' **(Participant 14)**	'It provides real-world examples of the content we are learning about that we work through (as opposed to it just being presented to us) which helps to consolidate the material.' **(Participant 32)**	'This can aid professionals in determining if a certain disease may be genetic or environmental in a patient. We could use bioinformatics for an oral microbiome analysis to determine how cariogenic the species composition of a patients microbiome is and therefore caries risk. We could also potentially use it to determine the genetic variation of response of patients to anaesthetics (sic).' **(Participant 15)**	'I now have a resource on hand that I can refer to for the rest of my career if I do have questions about the causation of certain oral diseases/conditions and the genes/proteins involved in different stages of development. It allows us to see what may have been impacted and at what point to result in a condition we may have observed.' **(Participant 25)**	'This database was a very helpful resource for me to find the exact information that I was looking for, without having to use outside recources (sic) or having to spend too much time looking for the information in academic papers.' **(Participant 29)**
	'I think it did improve my understanding of the genetics of tooth development and developmental anomaly because the database reinforced what I have learned from lecture.' **(Participant 4)**	'I think the lectures were done quite well to supplement the resource, but one thing that really helped in the resource was being exposed to the different gene names and conditions that they may affect. As the course work is separated for learning but sometimes we overlook how connected processes in development can be ...' **(Participant 30)**	'I would say yes because this database provided me with interactive and detailed genetic info by combining the content we covered in lectures with real-world data. In other words it helped me apply what I learned to a minimal extent.' **(Participant 7)**	'... having access to a biological database can help dentists acquire the information they need to help treat and advise their patients better by giving them a better understanding of the pathways and mechanisms involved in certain oral diseases.' **(Participant 12)**	'We can use these databases as a valuable clinical support tool. Access to this genetic information can help us with diagnosing patients with their developmental problems by understanding their genetic predisposition.' **(Participant 3)**	'It's also very handy as it is convenient and easy to access and saves you from needing to memorize all this information which can also lead to some uncertainty and self doubt.' **(Participant 6)**

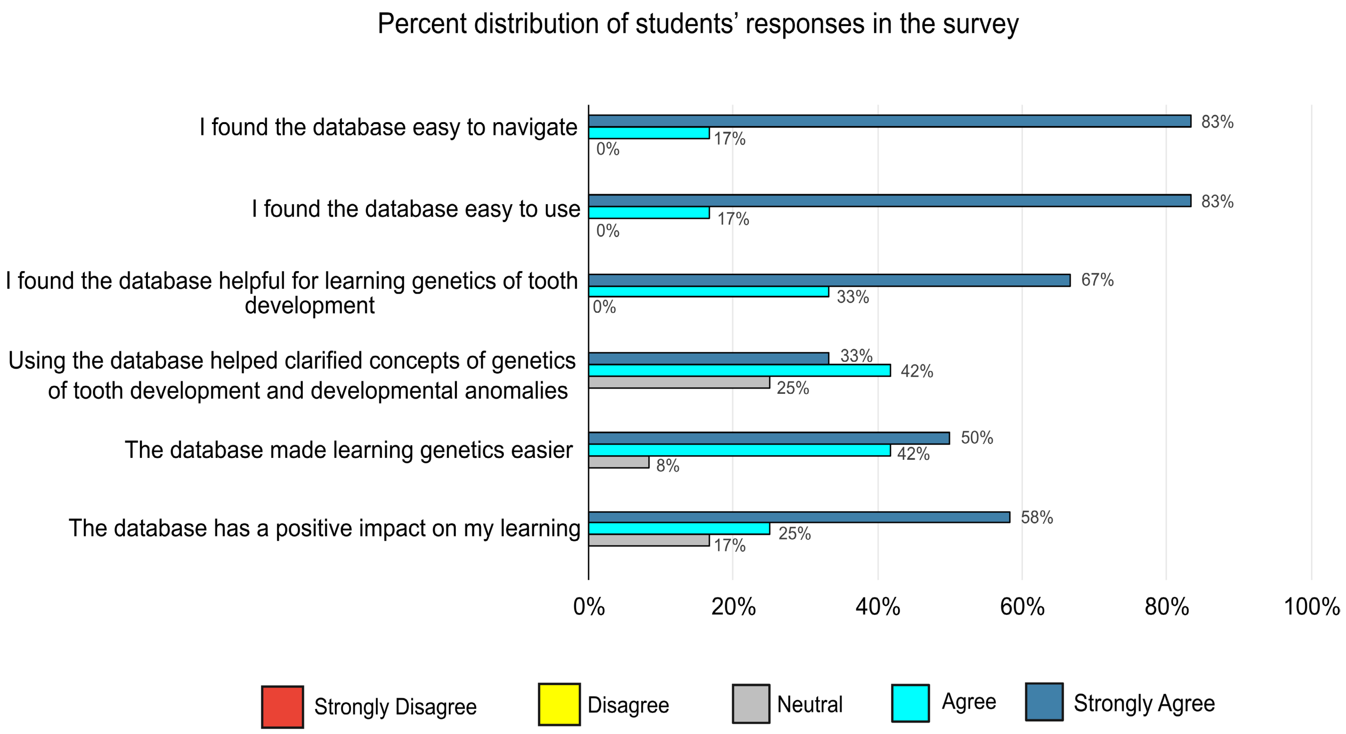

FIGURE 2 | Per cent distribution of students' responses in the survey. After completing the database lab activities, students were invited to participate in an online voluntary survey. Thirty-eight per cent ($n = 12$) of the DDS-I students completed the survey.

reported OMIM as complex and challenging to navigate [15]. A secondary database like Bioinformatics for Dentistry, which is more straightforward in architecture, can serve as a better teaching tool to improve genomic literacy in first- and second-year students.

In the traditional method of teaching genetics in dentistry, students were expected to memorise the names and functions of many genes, proteins and regulatory factors involved in the genetic regulation of tooth development, creating an unnecessary cognitive load on students. By introducing students to the biological databases, we aimed to equip them with the knowledge of where and how to find reliable genomic information and interpret it accurately. Several student comments showed that using a database broadened their understanding of the genetic regulation of tooth development. Many students were also relieved that knowing how to interpret genetic data would be helpful as they could not memorise this large dataset and stay current (Table 1).

> “*“Several student comments showed that using a database broadened their understanding of the genetic regulation of tooth development.”*”

We acknowledge that our results are based on a small sample size from a single cohort of dental students, which may impact the generalisability of our findings. Future studies can evaluate the long-term impact of database-infused teaching on students' perceived and measured learning of genetics. With the advancement of gene sequencing technology, the knowledge of genetics and the collection of genetic data are rapidly expanding beyond what is presented in textbooks. Application of a genomic database like Bioinformatics for Dentistry can benefit students beyond oral health professionals who are studying genetics, molecular biology, pathology, medicine, medical genetics and bioinformatics. In the future, we plan to introduce ‘Bioinformatics for Dentistry’ and other primary databases to the fourth-year DDS students and improve the functionality of the database based on students' feedback.

Author Contributions

Ava K. Chow: conceptualisation, data acquisition, formal analysis, methodology, project administration, writing – review and editing. **Nazlee Sharmin:** conceptualisation, data acquisition, formal analysis, methodology, project administration, writing – original draft.

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Ethics Statement

This study was reviewed and approved by the University of Alberta Research Ethics Board (REB 2). The ethics approval ID is Pro00107559.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Consent

The authors have nothing to report.

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Appendix A

For each question, please respond (click) with one answer that is the most appropriate for you according to the 5-point Likert scale, which describes (1) *Strongly disagree*, (2) *Disagree*, (3) *Neutral*, (4) *Agree*, (5) *Strongly agree*.

The survey questions were developed by the authors, based on the System Usability Scale (SUS) [10].

	Strongly disagree (1)	*Disagree* (2)	*Neutral* (3)	*Agree* (4)	*Strongly agree* (5)
I found the database easy to use.					
I found the database easy to navigate.					
I found the database helpful for learning genetics of tooth development.					
Using the database helped clarified concepts of genetics of tooth development and developmental anomalies.					
The database made learning genetics easier.					
The database has a positive impact on my learning.					