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Teaching Radiographic Caries Detection and Treatment Planning: A Seminar Using an Audience Response System

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Keywords
Teaching · Students · Dental education · Dental caries · Radiographic caries detection · Audience response system

Abstract
This study presents a seminar model for teaching radiographic caries detection and treatment planning at the Faculty of Dentistry, University of Oslo. The seminar is based partly on an audience response system (ARS) and uses patient cases to focus on caries risk assessment and treatment planning. This paper describes the seminar design, implementation, learning outcomes, and observational study of variability in caries registrations and students' attitudes to use of ARS. Dental and dental hygiene students participate in two seminar modules. Module 1 aims to develop and increase individual student skills in radiographic caries lesion detection, scoring, and differential diagnosis. Students perform trial registrations on bitewings using an ARS with anonymous live polling, and scorings are discussed in plenum. Students then perform individual registrations on 12 bitewing pairs. Using digital scoring, students detect and grade caries lesions on all approximal and occlusal tooth surfaces. After the session, students use the ARS to repeat scorings on selected tooth surfaces, and results are again discussed in plenum. Module 2 involves group exercises on 4 patient cases that are later presented with plenary discussions. In total, 1,624 caries registrations performed by 150 students attending the seminar between 2016 and 2018 were assessed for variability between students. As expected, variations in caries registrations were observed between students, mostly related to restored surfaces or tooth surfaces that were otherwise difficult to register. In 2022, 63 dental and dental hygiene students attending the seminar answered a questionnaire about use of ARS. The responses were scored using a five-point Likert scale. Overall, no significant difference in satisfaction with the ARS-based module was observed between dental and dental hygiene students (χ^2 test, $p > 0.05$). The majority of the students were positive toward the use of ARS (94%), but some disagreed on the role of ARS in usefulness for understanding the seminar content (3.2%), and in increasing their confidence in radiographic registration of caries (3.2%). The ARS-based module provides a positive learning environment that ensures student anonymity, interactivity, and engagement, and combined with the other seminar module gives students basic skills in caries detection and treatment planning.

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Introduction

In the framework of the 68th ORCA Congress in 2021 in Zagreb, Croatia, the ORCA Education Platform and the Association for Dental Education in Europe joined forces to celebrate the 10th anniversary of the European Cariology Curriculum for undergraduate dental students [Schulte et al., 2011]. One of the topics at this meeting was innovative teaching methods in cariology. The present paper describes a cariology seminar on the topic "radiographic caries detection, risk assessment, and management" that uses an audience response system (ARS).

ARS is an electronic system that allows participants to respond to, for example, multiple-choice questions using electronic devices or clickers [Kay and LeSage, 2009; Atlantis and Cheema, 2015]. Audience response is a type of interaction associated with the use of an ARS, to create interactivity between a presenter and its audience. By means of an ARS, large groups of participants can respond to test questions simultaneously and receive immediate feedback during a lecture or discussion [Kay and LeSage, 2009; Atlantis and Cheema, 2015]. In educational settings, ARS is also termed a student response system. ARS technologies have been adopted in many health and other professional educations to enable interactions between students and teachers or instructors [Kay and LeSage, 2009; Atlantis and Cheema, 2015]. Most often, students' responses are anonymous, which is considered to be a key advantage, allowing students to participate freely in the teaching session without fear of embarrassment or being singled out [Kay and LeSage, 2009; Atlantis and Cheema, 2015]. The results of students' responses are instantly collected and displayed graphically on a screen. Thus, teachers can modify the course of instruction, and students can work out misconceptions via peer or classroom discussion [Kay and LeSage, 2009; Atlantis and Cheema, 2015].

In dentistry, ARS technologies have been applied within disciplines such as oral and general anatomy [Abdel Meguid and Collins, 2017], oral and maxillofacial radiography [de Oliveira-Santos et al., 2018], restorative dentistry [Elashvili et al., 2008], orthodontics [Robson et al., 2015], pediatric dentistry [Johnson, 2005] as well as practical skills training courses [Wenz et al., 2014]. In cariology, ARS has been used in preclinical operative courses [Elashvili et al., 2008] and is recently reported for training in radiographic caries detection [Anamali et al., 2021].

Various studies report that students' overall feedback on use of ARS is positive, and students experience increased attention, engagement, and participation [Johnson, 2005; Elashvili et al., 2008; Robson et al., 2015; Abdel Meguid and Collins, 2017; de Oliveira-Santos et al., 2018]. However, to our knowledge, the majority of studies reporting use of ARS are from the USA, and information on use of ARS in dental education in Europe is rather limited. The aim of this observational study was to describe an interactive seminar model in cariology using ARS, present an example of variation in caries detection on bitewing radiographs, and explore students' attitudes to use of ARS.

Subjects and Methods

Ethics and Study Subjects

The study was performed according to relevant guidelines and regulations in Norway, and followed the STROBE guidelines. A preliminary enquiry was sent to the Norwegian Centre for Research Data (NSD) asking about permission to use the data from students' caries registrations collected from the digital questionnaire system (Nettskjema®). The NSD replied that given that the data were de-identified, use of the data in this publication did not require mandatory notification. No notification was necessary for the anonymous paper-based questionnaire regarding attitudes to ARS use.

The subjects in this study were undergraduate dental and dental hygiene students at the Faculty of Dentistry in Oslo, Norway. As part of their cariology course, 2nd-year dental hygiene students and 3rd-year dental students attend an obligatory seminar in radiographic caries detection, caries risk assessment, and caries control and management. At this stage of their study programs, both student groups have had teaching in basic principles of dental radiography but have little experience of examining patients. The dental students have only just started treating patients in the clinic, whereas the dental hygiene students have had somewhat more patient contact.

Study Design and Implementation

The seminar consists of two modules as shown in Figure 1. Use of an ARS is an important part of the first day of the seminar in teaching radiographic caries detection. In module 2, groups work on and discuss patient cases with different levels of caries risk that are essential for teaching caries risk assessment, caries control, and management. The overall learning outcomes established for the seminar are training in (1) radiographic caries detection and registration, (2) caries activity and risk assessment, and (3) individualized caries control and treatment planning.

Seminar Module 1 – Digital Caries Detection Exercises and Use of the ARS

Module 1 of the seminar consists of individual caries detection and staging exercises on bitewing radiographs showing both enamel and dentine caries lesions. The radiographs were selected from the faculty's electronic patient journal system. The module provides bulk training in radiographic caries lesion detection, registration, and differential diagnosis. Students detect and stage approximal and occlusal surfaces using a standardized scoring system [Amarante et al., 1998]. As there are no clinical photos avail-

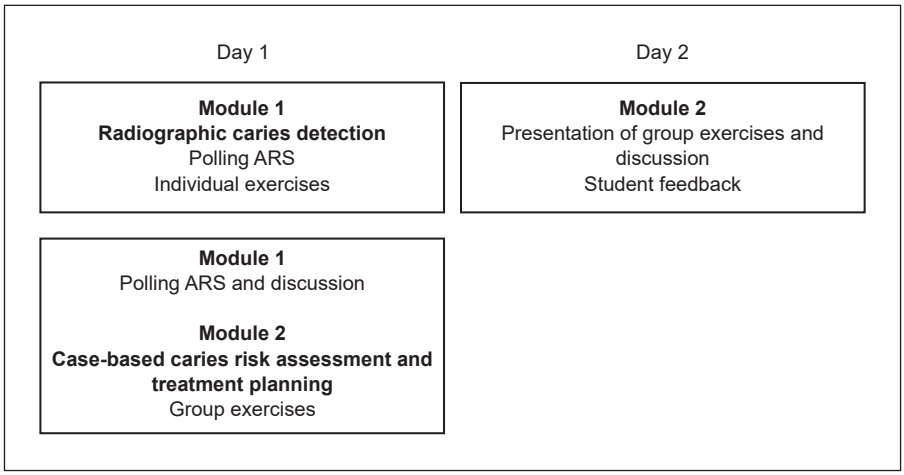


Fig. 1. Illustration of the seminar outline.

able, most attention is given to the approximal surfaces. Tooth surfaces are recorded as having either no sign of caries (stage 0), or, a radiolucency extending into the outer half of the enamel (stage 1), the inner half of the enamel (stage 2), the outer third of the dentine (stage 3), the middle third of the dentine (stage 4), the inner third of the dentine (stage 5) [Amarante et al., 1998], or as being "*not possible to register*." Students are initially shown several bitewing radiograph images and asked to perform trial caries registrations of specified tooth surfaces using an ARS integrated into a PowerPoint presentation (Turning Point, Technologies LCC), with anonymous live polling. They detect and stage the caries lesions and record their answers using hand-held response cards. The results of the polling for each tooth surface are then displayed for all students on the auditorium screen and are discussed in plenum. Students are encouraged to ask questions in order to clarify possible misunderstandings.

After the trial registration session, the students complete 12 compulsory digital exercises, each consisting of 2 patient bitewings. Data collection is handled by questionnaires created with nettskjema.no, a survey solution developed and hosted by the University of Oslo. The students are asked to score the bitewings individually; however, they are also permitted to discuss the bitewings as learning partners. Although there is no direct performance feedback, there are usually two-three teachers available for questions/queries and discussions during the scoring session. The data are transferred to the database and allow teachers to examine variation in caries detection and staging among students, as well as the time students spend for the registrations. A total of 1,624 caries registrations were performed by 150 students attending the seminar from 2016 to 2018, and data on the variability of registrations for three dental-student groups (n = 114) are presented in the results section.

In the second part of module 1, the students are asked to repeat scorings on selected bitewing pairs using the ARS. The bitewings with specific tooth surfaces are chosen from those cases that had been perceived as challenging or difficult by the students. An example of such a case is shown in Figure 2. The results of the polling are then displayed on the large screen and discussed in plenum in order to help clarify uncertainties when interpreting the radiographs. Follow-up radiographs of several bitewing patient cases are also shown, giving the opportunity to assess and discuss the topic of caries lesion progression. Caries lesions both with and without obvious radiographic signs of progression are pointed out and discussed with the students.

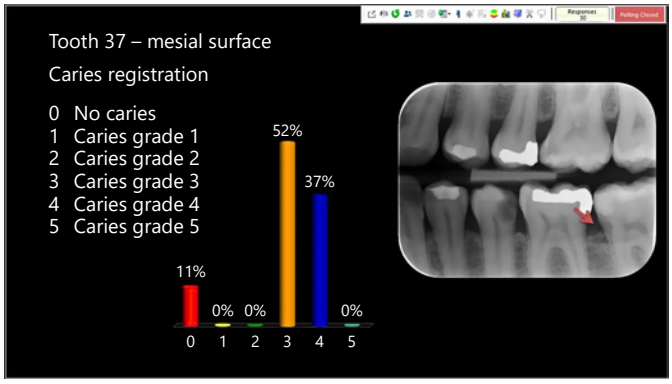
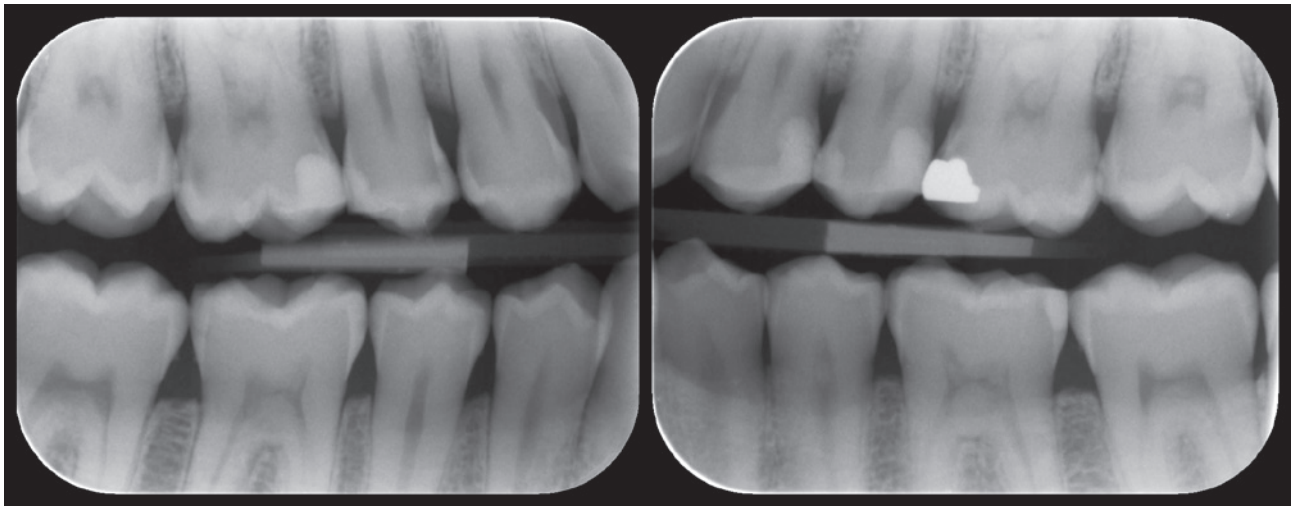


Fig. 2. Screenshot of the presentation after polling of a left bitewing where students are asked to register possible caries on the mesial surface of the lower left second molar. Half of the students registered a radiolucency extending into the outer third of the dentine (stage 3) and another third registered the radiolucency as being in the middle-third of the dentine (stage 4). The remaining students recorded the tooth surface as healthy (stage 0).

Seminar Module 2 – Patient Cases Involving Caries Activity and Risk Assessment and Individualized Treatment Planning

In this part of the seminar, students work in predesignated groups on 4 patient cases. Based on the radiographs and information on patient history provided, they discuss the cases and prepare a presentation for each patient focusing on caries detection, individual caries risk assessment, and treatment planning. Three days later, on day 2 of the seminar, the groups present their work, and the cases are discussed in plenum. Typical examples of topics that are discussed include patient history (i.e., patients' use of medications, socio-economic aspects); more specific oral patient factors (i.e., previous caries experience, dry mouth, sugar consumption, and oral hygiene); preventive factors (i.e., compliance related to



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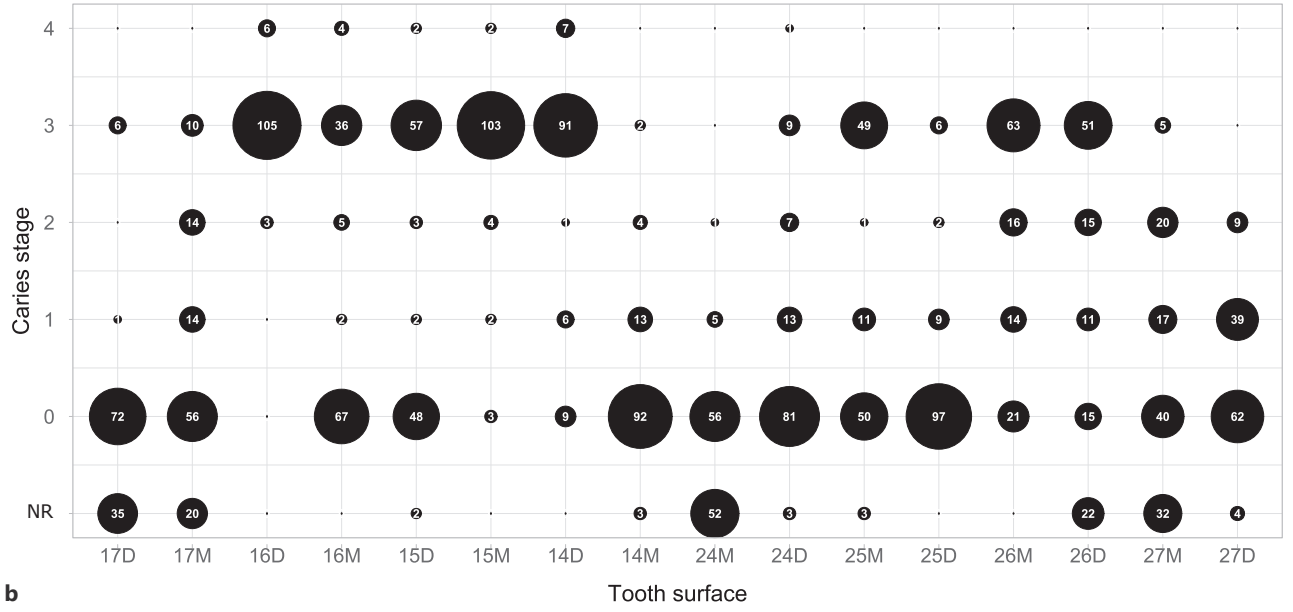

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Fig. 3. Illustration of the variation in the students scoring of caries on premolars and molars in the maxilla of one bitewing pair. **a** Selected bitewing from the digital caries registration exercises. **b** Bubble plot showing the variation in caries staging among students for the bitewing radiographs shown in **a**. The bubble plot shows the number of registrations for each caries stage for the approximal surfaces of upper premolars and molars as recorded by the three dental-student groups (n = 114 students/registrations per tooth surface). The number of students that registered each tooth surface as "*not possible to register*" is shown below the zero line (NR).

use of fluorides, dietary advice, and oral hygiene instruction); and nonoperative and operative caries management.

Digital Seminar

Due to the COVID-19 pandemic, a digital version of the seminar was developed and held in the spring of 2021. The teaching platform used was Zoom, and the hand-held response cards for ARS in trial caries registrations were replaced with a polling system in the Zoom platform. Trial registrations and anonymous polling of caries stages were therefore performed in a similar way as for the physical seminar. During the digital seminar, students worked as learning partners in predesignated "breakout" rooms in Zoom. Students were able to invite a teacher to visit their breakout room if they had questions. The teachers also visited the breakout rooms

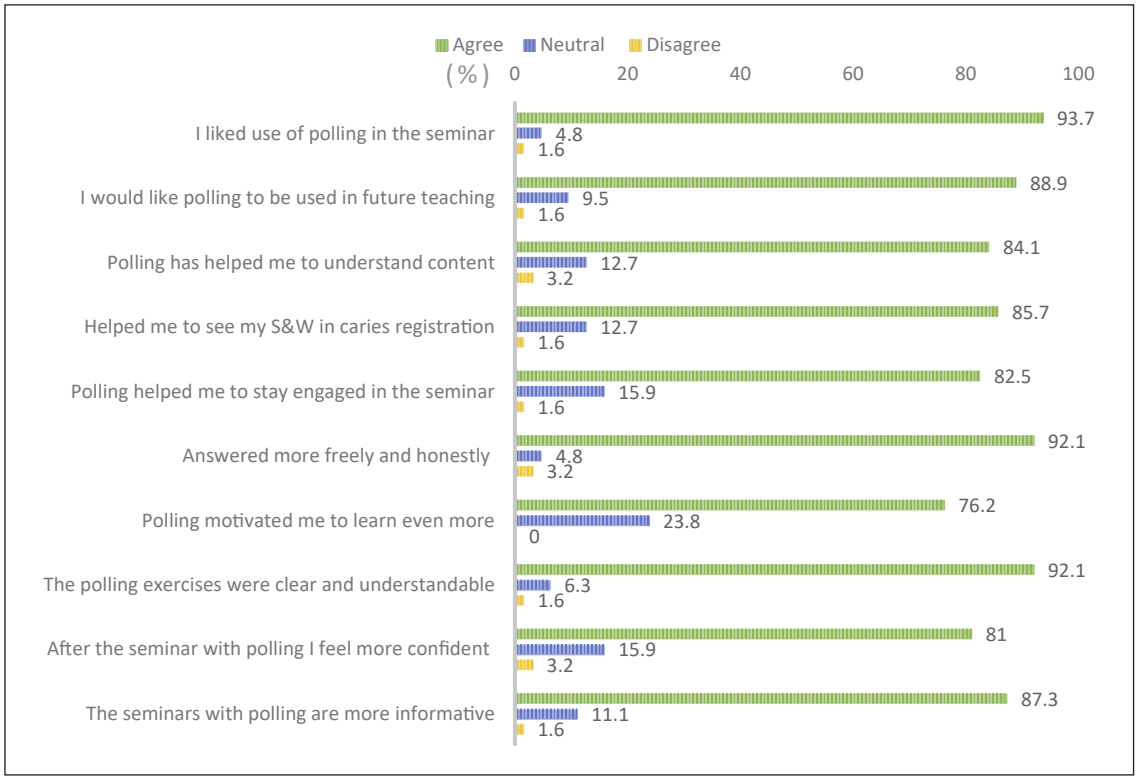

Fig. 4. Attitudes toward use of ARS with anonymous polling in the seminar among dental and dental hygiene students ($n = 63$). S&W, strengths and weaknesses. (An online supplementary table is available showing the complete statements.)

during the session to make sure that the students were managing well and answered any questions. In 2022, new adjustments were made. A digital platform was used on the first day of the seminar, whereas the group presentations and discussions on day 2 were held as a physical seminar.

Student Evaluation – Use of ARS in the Seminar

The seminar was first implemented in 2014, and ARS was integrated into the seminar in 2016. For evaluation and further development of the seminar, the students were asked to give their feedback and complete an anonymous paper-based evaluation form. The evaluation form contained two open-ended questions: (i) *what was positive/functioned well*? and (ii) *what was negative/can be improved*?, with a specific focus on the seminar content, learning material, the quality of the teaching, their own efforts, and their learning outcomes. The students' feedback is used to adjust and further develop and improve the seminar modules.

In the 2022 seminar, students' attitudes related to use of ARS in the seminar were explored using an anonymous paper-based questionnaire containing 10 statements (online suppl. Table, available at www.karger.com/doi/10.1159/000526109) adapted from a questionnaire used by Elashvili et al. [2008]. Sixteen dental hygiene students and 47 dental students answered the questionnaire. The responses were scored on a five-point Likert scale with the alternatives "strongly agree," "agree," "neutral," "disagree," and "strongly disagree" and further transformed into three categories: agree (strongly agree or agree), neutral (neither agree nor disagree), and disagree (disagree or strongly disagree).

Statistical Analysis

In order to assess variation in the digital caries detection exercises, data that were collected from Nettskjema were exported to excel and anonymized before further analysis using R Statistics [R Core Team, 2017]. Data collected from the evaluation of the seminar were processed and analyzed using SPSS statistical program package (IBM SPSS 28.0; SPSS Inc., Chicago, IL, USA). Frequency distribution was used for presenting descriptive results, and χ^2 test was used to test differences in responses between dental and dental hygiene students. The level of statistical significance was set at 5%.

Results

Digital Caries Registration Exercises

Variation in the students' digital registration exercises was assessed and visualized. As an example of registrations made by the three dental-student groups ($n = 114$), the variation in staging of approximal surfaces of upper premolars and molars for one bitewing pair is presented in Figure 3. The bubble plot (Fig. 3b) shows the number

of scorings of each caries stage for selected tooth surfaces. As expected, variations in caries registrations were observed among students. For some tooth surfaces, there was strong agreement between the students, while for other tooth surfaces, the registrations varied significantly between the students.

Student Evaluation – Use of ARS in the Seminar

The frequency distribution of students' responses to statements about use of ARS and polling in the seminar is shown in Figure 4. There were no statistically significant differences in responses between dental and dental hygiene students (χ^2 test, $p > 0.05$), and the results for these two groups were therefore pooled. The results showed that the majority of the students were positive toward the use of ARS in the seminar (94%), found the exercises clear and understandable (92%), and agreed that use of polling helped them to answer more freely and honestly (92%). On the other hand, almost one quarter of the students (24%) responded in a neutral way to the statement "*Polling motivated me to learn even more.*" The highest proportion of disagreement (3.2%) was related to the statements "*Polling has helped me to understand content better*", "*After the seminar with polling I feel more confident in radiographic registration of caries*", and "*The anonymity in polling helped me to answer more freely and honestly*".

Discussion

This study presents an interactive model for teaching radiographic caries detection and treatment planning in an undergraduate seminar based partly on use of an ARS. Although use of ARS in dental education has increased during the last decades [Johnson, 2005; Elashvili et al., 2008; Wenz et al., 2014; Robson et al., 2015; Abdel Meguid and Collins, 2017; de Oliveira-Santos et al., 2018; Anamali et al., 2021], there are few studies published about its use in teaching cariology. In line with previous reports [Johnson, 2005; Elashvili et al., 2008; Robson et al., 2015; Abdel Meguid and Collins, 2017; de Oliveira-Santos et al., 2018], the students gave an overall positive feedback to use of ARS in the first seminar module. A high proportion of students agreed with the majority of the statements, and this suggests that many of the advantages of ARS previously documented in the literature were experienced by the students in the study.

The rationale for implementation of ARS in this seminar was mainly for improved student interactivity and engagement, and did not include an assessment of students' knowledge retention. Relatively few studies have evaluated the impact of ARS on short- or long-term learning outcomes in health students and professionals, and recent systematic reviews have concluded that there is little of evidence on effectiveness of ARS technologies for improvement in learning outcomes [Atlantis and Cheema, 2015; Hussain and Wilby, 2019]. Further research is therefore warranted to investigate learning outcomes from using ARS as compared to conventional teaching methods in dental education [Elashvili et al., 2008; Wenz et al., 2014; Robson et al., 2015; Anamali et al., 2021].

The digital exercises using the Nettskjema data collection tool provided an opportunity for students to practice detection and staging of dental caries on many different bitewings at a time when they are starting to see patients in the clinic and had little training in caries lesion detection and differential diagnosis. As expected, variations in caries registrations were observed among students. For some tooth surfaces, there was strong agreement between the students, while for other tooth surfaces, the registrations varied significantly between the raters (shown in Fig. 3a, b). The most likely reasons for this may be that the tooth surface was not completely visible (e.g., 17D), that there was overlapping of tooth surfaces (e.g., 17M), that there was poor radiographic contrast (e.g., 24M), and that surfaces were restored (e.g., 24D and 26M). Surfaces that were not possible to register were typically where there was too much approximal surface overlapping or where the tooth surface was not present.

After the seminar, students gave feedback about the large amount of time set aside for the digital exercises. We noted that while some students struggled to complete the obligatory exercises, others completed them and additional 5 exercises that were not obligatory. On a positive note, some students who did not finish during the time set aside often asked if they could have access to the bitewings after the seminar. Students also commented on the lack of immediate feedback to their caries registrations as they would have liked to know whether their scorings/answers were correct. This is understandable in a learning situation, and plans are underway to provide this for future seminars.

The use of a digital data collection tool also provided the possibility to further develop the seminar and monitor student performance on an individual, as well on a group level. Furthermore, during the pandemic, the digital caries detection and staging exercises using the Nettskjema data collection tool made it possible to relatively easily transform the teaching content from a fully physical seminar to a fully digital seminar.

The second module of the seminar was mainly driven by the students working in predesignated groups. Predesignated groups meant that they often worked with other students than if they had been allowed to choose learning partners themselves. The general student feedback to the group work was that they liked working together and discussing the patient cases without a teacher present. This feedback was the same for the digital seminar as for the physical seminar. Each group presented one of the patient cases on the second day of the seminar. The presentations provided an environment for discussions about patient caries risk assessment, as well as individual caries control and treatment planning. It is therefore important that the teaching material is chosen and designed to provide relevant learning outcomes.

Regarding the resources used for this type of seminar, depending on which ARS is used, the preparation and implementation of ARS-based courses may require some IT assistance. Furthermore, hand-held response cards and matching software for ARS can be costly if they are not readily available at the teaching institution. Fortunately, use of the polling function with digital teaching using systems, such as Zoom, are usually less expensive if they are already implemented. The use of more than one teacher as described in this seminar is also a question of resources. In particular, on the second day of the seminar, discussions about the patient cases were improved when two or three qualified teachers participated with their varying expertise. The seminar is actually held three times within a relatively short time period; once for the dental hygiene students and twice for the dental students where they are divided into two groups so as not to have too many students at once. This secures the necessary interactivity and allows the teachers to give enough follow-up for each group during the seminar.

To our knowledge, this is the first study describing use of ARS in a seminar for teaching cariology in a Scandinavian dental education and students' attitudes toward use of ARS in the seminar. Obvious strengths of this ARS- and case-based seminar are the relatively small student groups and the presence of usually two or three teachers during the discussions, thus facilitating interactivity between students and teachers. In addition, the combination of patient cases and use of ARS is well accepted by the students. Interestingly, we noted a high degree of student satisfaction irrespective of whether the seminar was given physically or digitally. This observation indicated that both students and teachers had acquired sufficient competence in digital learning and teaching after the COVID-19 outbreak. In line with many other studies evaluating the use of ARS technologies, one limitation of our study was the lack of assessment of learning outcomes. The students participating in our seminar were relatively inexperienced, and generalizability of the results is therefore limited to similar settings. It would be of interest to investigate whether final-year students who are more confident in caries detection and registration would be as positive to use of ARS.

"Caries risk assessment, diagnosis and synthesis" is one of the five main domains in the European Core Curriculum in Cariology [Schulte et al., 2011], and this domain is fundamental for clinical decision-making. In addition to clinical examination, radiographic caries detection is the most frequently used diagnostic tool in daily dental practice [Rindal et al., 2010]. Skills in radiographic caries detection and lesion staging are therefore important for monitoring disease process and supporting decisions for nonoperative versus operative caries treatment [Signori et al., 2018]. However, radiographic caries detection is challenging even for experienced general dental practitioners [Signori et al., 2018]. It is therefore of utmost importance that dental and dental hygiene students are confident in using the method and are aware of both advantages and limitations of radiography as an additional method in caries diagnosis. Based on our experience, an interactive seminar with focus on diagnostics and treatment planning with plenary discussions and clarification of misunderstandings provides students with the set of basic skills and increased self-confidence in the clinic.

In conclusion, based on student evaluation, this seminar provided a positive and interactive learning environment. The use of an ARS in the first module ensured student anonymity, interactivity, and engagement in an early learning phase. The combination of patient cases and ARS gave students good basic skills in caries detection and treatment planning.

Statement of Ethics

This study is based on anonymous data, and ethical approval was not required in accordance with national guidelines. According to the regulations of the Norwegian Centre for Research Data (NSD), no notification was necessary for use of the data collected from the digital questionnaire system or for the anonymous paper-based questionnaire regarding attitudes to use of ARS. Since data were collected for quality assurance, no written informed consent from participants was required.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

Alix Young, Elin Giertsen, and Rasa Skudutyte-Rysstad contributed to the conception and design of the seminar. Gerald Torgersen performed the data collection from the net-based registration exercises using Nettskjema. Alix Young and Rasa Skudutyte-Rysstad performed the data collection from the seminar evaluation. Alix Young, Elin Giertsen, Rasa Skudutyte-Rysstad, and Gerald Torgersen contributed to data analysis and interpretation, drafted the manuscript, critically revised it, and approved the final version.

Data Availability Statement

All data that support the findings of this study are included in this article. Further inquiries can be directed to the corresponding author.

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