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Interactive Online Modules for Dental Education: A Practical Example of Gagne's Nine Events of Instruction

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ABSTRACT

Effective and engaging learning experiences are crucial in dental education, especially in the field of dental materials science, as previous approaches were largely through didactic teaching. Interactive online modules have emerged as valuable supplemental tools to enhance dental education. It offers interactive elements, promotes active learning, and provides an immersive, self-paced learning environment. This article highlights the use of Gagne's Nine Events of Instruction as a practical framework to design and implement interactive online modules in the dental materials science curriculum. Gagne's model provides a structured approach to instructional design, improving students' engagement and their learning process. The development of interactive online modules follows Gagne's model, including gaining attention, informing students of objectives, stimulating the recall of prior knowledge, presenting new material, providing guidance, eliciting performance, providing feedback, assessing performance, and enhancing retention and transfer. Students' perceptions and feedback can be evaluated at the end of the online modules. In short, this article provides a systematic approach to the design and implementation of interactive online modules, ultimately improving the educational outcomes for dental and other health profession students.

Keywords: *Active learning, Dental education, Online education, Pedagogy, Undergraduate*

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INTRODUCTION

In health profession education, it is crucial to provide students with effective and engaging learning experiences that foster deep understanding and knowledge retention (1). Dental materials science is a fundamental course in most dental curricula that lays the groundwork for understanding the properties and applications of various dental materials, such as composites, ceramics, metals, and polymers (2). This course is essential to prepare dental

students for clinical practice by equipping them with the knowledge and skills required to select, handle, and apply different dental materials to provide optimal treatment outcomes. Future-ready graduates need to know how to evaluate the properties, strengths, and limitations of various dental materials, allowing them to make evidence-based decisions when choosing materials for dental treatments (3, 4). Traditional teaching methods, such as didactic lectures and laboratory demonstrations, have been the cornerstone of dental materials science education for decades (5). While these methods have their merits, they often rely on passive learning and limited student interaction, potentially hindering critical thinking, problem-solving abilities, and practical skills (6, 7). Recognising these limitations, educators have sought innovative approaches to enhance the teaching and learning of dental materials science (8).

Interactive online modules have emerged as valuable supplemental tools to complement existing instructional methods. They harness the power of technology to engage students actively, provide dynamic and interactive learning experiences, and bridge the gap between theoretical knowledge and practical application (9). Interactive online modules, designed specifically for dental materials science education are expected to offer a range of interactive elements, including multimedia presentations, simulations, case studies, interactive quizzes, and virtual experiments. These instructional design methods create an immersive and self-paced learning environment, enabling students to navigate complex concepts at their own pace (10). Moreover, the integration of visual and interactive components further enhances students' understanding and retention of information (9). Previous studies have found that interactive online modules bring several advantages to both students and educators in health profession education (11–13). First, they promote active learning by encouraging students to engage with the contents actively, resulting in deeper comprehension and knowledge retention (12). Second, online modules provide students with opportunities for self-assessment, immediate feedback, and self-directed learning, enabling them to identify areas for improvement and consolidate their understanding of the contents (13). Additionally, these modules offer flexibility in terms of accessibility, allowing students to access educational content at their convenience, and accommodating diverse learning preferences and schedules (14).

The integration of interactive online modules is undeniably valuable in enhancing the learning experience among students in dental materials science courses. To effectively incorporate these modules into the dental materials science curriculum, instructional design (e.g., careful planning, integration, and alignment with learning objectives) is essential. Educators need to consider the appropriate timing and sequence of module usage within the curriculum to ensure coherent and seamless learning instruction. In this context, Gagne's Nine Events of Instruction can be seen as a systematic approach to design instructions (15). It consists of a set of instructional principles that aim to enhance the learning process and improve learner engagement (16). Gagne's Nine Events of Instruction is widely used in schools (15), and several attempts have been reported in medical education (17, 18), as well as nursing education (19). Nevertheless, its application is underexplored in dental education. This article describes the practical use of Gagne's Nine Events of Instruction as a framework for designing, implementing, and evaluating interactive online modules that promote student engagement and facilitate active learning, particularly in the dental materials science curriculum.

INSTRUCTIONAL DESIGN MODEL: GAGNE'S NINE EVENTS OF INSTRUCTION

Robert Gagne (20), a renowned educational psychologist, proposed a systematic approach to instructional design known as the Nine Events of Instruction. This model provides a structured framework for designing and enhancing students' overall learning experiences. These nine events include: (1) gaining attention; (2) informing students of objectives; (3) stimulating recall of prior knowledge; (4) presenting content; (5) providing guidance; (6) eliciting performance; (7) providing feedback; (8) assessing performance; and (9) enhancing retention and transfer. Each event serves a specific purpose in the learning process. By employing this framework, educators can create engaging and coherent learning modules that capture students' attention, facilitate comprehension, encourage active participation, and promote long-term retention of knowledge and skills (21). Next, each event in the development of interactive online modules is described (Figure 1).

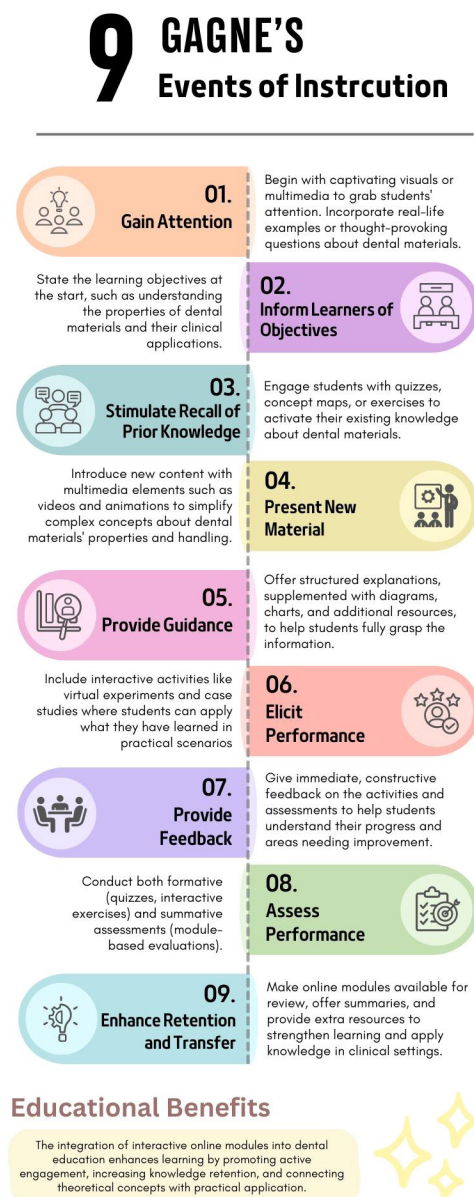


Figure 1: Step-by-step in developing interactive online modules for dental materials science course using Gagne's Nine Events of Instruction.

Source: Author GSSL.

Event 1: Gain Attention

The first event aims to capture students' attention and stimulate their interest in the topics. It serves as a hook to draw students into the content and create an engaging learning environment. In the online modules, an attention-grabbing introduction can be presented, highlighting the basic properties and applications of dental materials. The interactive online modules can employ various strategies to pique students' curiosity and motivate them to explore further in the selection of dental materials. These strategies may include:

1. Provide engaging visual or multimedia elements: Incorporating visually appealing graphics, images, or videos at the beginning of the module which can immediately capture students' attention. Similarly, integrating multimedia elements such as audio narration or interactive animation can provide a multisensory learning experience. By presenting information through different modalities, student attention can be sustained.
2. Present thought-provoking questions: Present students with thought-provoking questions or challenging scenarios to stimulate their cognitive processes and encourage active engagement. These questions can be posed as an introduction to the topic or as prompts throughout the module to keep students actively thinking and reflecting.
3. Provide real-life examples: Sharing real-life examples or case studies that demonstrate the practical relevance of the course content can help students understand the value and applicability of what they are about to learn. This can be done through interactive scenarios or narratives that immerse students in realistic situations.
4. Provide intriguing statements: Starting the module with intriguing statements or surprising facts related to the topic can instantly capture students' attention. These statements can generate curiosity and motivate students to understand the underlying concepts or principles of each dental material.
5. The primary goal of this event is to create a compelling introduction that captures students' interest and establishes the relevance and importance of the upcoming content. By employing a combination of these interactive strategies, online modules can effectively engage students and set the stage for a meaningful learning experience.

Event 2: Inform Learners of Objectives

At the beginning of each module, the objectives should be stated explicitly, outlining what students are expected to learn and accomplish by the end of the modules. These objectives serve as a roadmap, allowing students (and teachers) to track their progress throughout the module. Some examples of learning objectives are:

1. Explain the physical and chemical properties of dental materials, such as metals, ceramics, polymers, and composites.
2. Evaluate the biocompatibility of dental materials and their interactions with oral tissues.
3. Identify the proper manipulation techniques for various dental materials.

4. Appraise the latest advancements in dental materials technology.
5. Apply critical thinking skills to select appropriate dental materials for specific clinical scenarios.

By stating the objectives explicitly, students can gain a clear understanding of what they are working towards and what they will be able to achieve upon completing the module. This helps in aligning their expectations and focusing their attention on the specific knowledge and skills they need to acquire. Moreover, the stated objectives serve as a measure of progress throughout the module. As students engage with the interactive online modules, they can refer to the objectives to track their own progress. This allows them to gauge their understanding of the material and identify areas that may require further attention and review. In addition to the initial statement of objectives, it can also be beneficial to periodically revisit and reinforce the objectives throughout the module.

Event 3: Stimulate Recall of Prior Knowledge

To facilitate meaningful learning, students' prior knowledge must be activated and connected to new information (to be learnt). The online modules should incorporate interactive virtual group activities, such as quizzes, concept maps, or short exercises, to prompt students to recall relevant concepts from previous lessons. By engaging students in these activities, their minds are primed to retrieve relevant information from their long-term memories and prepare them to make connections with new materials.

First, quizzes serve as a useful tool to assess students' knowledge, while also triggering the retrieval of relevant information. They can be designed to include questions that require students to recall key concepts, principles, or terminology covered in earlier modules or lectures. Second, concept maps provide a visual representation of the relationships between different concepts and allow students to organise and connect their existing knowledge to new information. By constructing concept maps, students can identify links and associations between previously learned concepts and the new materials. This process will help them to consolidate their understanding and develop a more comprehensive mental framework. Third, short exercises, such as problem-solving tasks or case studies, require students to apply their prior knowledge to solve real-life scenarios. By presenting practical situations, these exercises prompt students to recall relevant information and apply it to solve problems or make informed decisions. This active engagement strengthens their understanding and prepares them to integrate new knowledge effectively.

Event 4: Present New Material

This event will involve the delivery of new information or concepts to students in a structured and engaging manner, such as introducing students to the properties, characteristics, and applications of various dental materials. Online modules can leverage multimedia elements such as videos, animations, and interactive simulations to enhance the presentation of this content. This multimedia approach will cater to different learning styles and enhance students' understanding of complex dental materials concepts.

Utilising multimedia elements serves several purposes. First, videos and animations can visually demonstrate complex concepts, making them more understandable and relatable for students. For example, a video can illustrate the manipulation techniques of a dental composite and the fabrication process of ceramic restoration. Visual representations help

students grasp the practical aspects of dental materials, enhancing their understanding and bridging the gap between theory and application. Furthermore, interactive simulations provide an immersive learning experience, enabling students to actively engage with the material. They can virtually manipulate dental materials, explore their properties, and observe their behaviour under different conditions. This virtual hands-on approach fosters experiential learning, allowing students to develop a deeper understanding of the subject matter. Some students may prefer visual learning, while others may benefit from auditory or kinaesthetic learning. By incorporating videos, animations, and interactive simulations, the online modules will provide multiple avenues for students to absorb and process new information according to their individual preferences. Each module should follow a well-organised outline, guiding students through the essential topics and facilitating a comprehensive understanding of dental materials.

Event 5: Provide Guidance

After presenting new material in the online modules, students need guidance to understand and interpret the information effectively. The online modules must provide step-by-step explanations to break down complex concepts into manageable parts. This approach ensures that students can grasp the foundational principles before moving on to more advanced topics. By offering clear explanations, the modules allow students to build a solid understanding of the presented content. Visual aids can be integrated into the online modules to enhance comprehension. Diagrams, charts, images, and interactive simulations can also be used to visually represent abstract concepts and processes. Examples are to be included to illustrate the practical application of the presented concepts. In addition to step-by-step explanations, visual aids, and examples, the online modules can also provide links to additional resources and references. These resources encourage further exploration and self-directed learning. Students can delve deeper into specific topics, access research articles, or explore related educational materials. By providing these resources, the modules empower learners to expand their knowledge and develop a more comprehensive understanding of dental materials science.

Event 6: Elicit Performance

The online modules should include interactive activities and assessments to reinforce learning and assess student comprehension. Students will have the opportunities to apply their knowledge through virtual experiments, case studies, or problem-solving exercises. Feedback and explanations can be provided to enhance their understanding and address any misconceptions. The inclusion of interactive activities and assessments has multiple purposes. First, it allows students to practice and reinforce their knowledge by applying it in different contexts. Moreover, interactive activities and assessments also serve as a means of assessing students' comprehension and progress. By evaluating their performance in these activities, instructors can gauge the level of mastery attained by students and identify areas that require further attention or clarification. This formative assessment approach enables timely feedback and intervention.

Event 7: Provide Feedback

Feedback plays a crucial role in the learning process, allowing students to identify their strengths and areas for improvement. The online modules should incorporate feedback on interactive activities and assessments, providing students with valuable insights into their performance. This feedback will not only inform students about the correctness of their responses but will also explain the underlying principles and rationales. Furthermore, constructive feedback will help students identify and rectify their misconceptions or gaps in knowledge. It also encourages critical thinking and reflection, enabling students to develop metacognitive skills and refine their learning strategies. By incorporating constructive feedback, the online modules empower students to play an active role in their learning. They can self-assess their progress, identify areas of strength and weakness, and make informed decisions on how to improve.

Event 8: Assess Performance

Periodic assessments are essential to monitor students' progress and determine their level of mastery. The online modules will include formative and summative assessments, such as quizzes, interactive exercises, and module-based evaluations. These assessments will help students gauge their understanding and provide instructors with valuable data to identify areas that require additional support. Formative assessments, such as quizzes and interactive exercises, are designed to provide ongoing feedback to students during the learning process. These assessments help students gauge their understanding of the material, identify areas of weakness or misconceptions, and adjust their learning strategies accordingly. On the other hand, summative assessments, such as module-based evaluations, are typically administered at the end of a module or a specific learning unit. These assessments aim to measure students' overall comprehension and mastery of the material covered. They provide a comprehensive review of the students' knowledge and skills, allowing instructors to evaluate their performance against predefined learning objectives (Event 2). Finally, the results of the summative assessments determine whether the learning objectives have been achieved or not.

Event 9: Enhance Retention and Transfer

The last event aims to reinforce long-term retention and transfer of knowledge. To reinforce the long-term retention of knowledge, online modules can be made accessible to students after completing them. Students can revisit the content and assessments a few months after or during clinical years. By revisiting and summarising core concepts, students can consolidate their knowledge and improve their ability to retain information over time. Next, to facilitate the transfer of knowledge, online modules should conclude with a summary of key concepts and highlight their practical applications in real dental practice. Additional resources such as review materials and interactive flashcards can be provided to support ongoing revisions and facilitate knowledge transfer to future clinical contexts. By highlighting how knowledge can be applied to clinical scenarios, students can better understand the relevance and importance of the material. This connection to real-world contexts motivates students to enhance their engagement with the content.

DISCUSSION

Integrating interactive online modules into dental and health profession courses offers significant benefits. These modules serve as valuable supplemental tools to enrich traditional classroom experiences (22). They can be strategically integrated into the course structure, allowing students access to them at specific points in the curriculum to supplement face-to-face lectures and practical sessions. Furthermore, aligning module content with course objectives enables students to reinforce key concepts through self-paced learning. It is crucial to ensure student access and meet technical requirements for the successful implementation of interactive online modules (23). Modules should be easily accessible through a user-friendly online platform, compatible with various devices such as laptops, tablets, or smartphones. It is also essential to provide clear instructions on module access and navigation, including necessary software or plugins. Additionally, addressing different internet speeds is vital for equitable access, considering offline alternatives or downloadable resources for students with limited internet access (24).

Resistance to change or unfamiliarity with online platforms may impede faculty members from embracing the benefits of interactive modules (25). Therefore, adequate training and support, focusing on instructional design principles, Gagne's Nine Events, and multimedia integration are needed to ensure the successful integration of interactive online modules (26). Training should also cover facilitating student engagement and collaboration in the online environment. Collaboration with instructional designers and e-learning specialists is crucial for developing high-quality modules (27). Moreover, ongoing support and access to technical assistance should be provided to faculty members to address any challenges or technical glitches that arise during the implementation process (28). Engaging students in online modules is essential for active learning and knowledge retention. Interactive online modules should be designed to stimulate critical thinking, problem-solving, and collaborative learning among students. Furthermore, promoting peer-to-peer interaction through discussion forums or virtual group activities can foster a sense of community of practice and provide opportunities for knowledge sharing and collaboration among students (29).

Undeniably, an essential aspect of implementing interactive online modules is the development of appropriate assessment and evaluation methods (30). Ongoing evaluation of module effectiveness, through surveys or feedback mechanisms, can continuously improve and refine students' learning experience (31). With the growing prevalence of interactive online modules in educational settings, ethical considerations must be prioritised, specifically regarding the privacy and confidentiality of students' personal information and data (32). As students engage with online modules, they may provide personal information or data related to their performance, such as quiz scores or completion rates. Educators and institutions are responsible to ensure appropriate security measures and protect sensitive information from leaks. This includes employing robust data encryption techniques, secure user authentication processes, and regular monitoring of data access and usage (33). Moreover, obtaining informed consent from students regarding the collection and use of their data is vital (34). Clear communication regarding data privacy policies and procedures should be provided, assuring students that their information will only be used for educational purposes and will not be shared with third parties without their consent. It is also crucial to respect intellectual property rights and ensure that all module materials adhere to copyright laws and regulations (35). Educators and content creators should seek appropriate permissions and licenses for any copyrighted material incorporated into the

modules. Alternatively, they should create original content or use openly licensed resources that allow reuse and modification under specified conditions. Proper attribution should be given to the original authors or creators of any referenced or used content, acknowledging their intellectual contributions (36).

Several challenges and limitations need to be addressed to ensure successful implementation of the interactive online modules. A primary hurdle is the need for robust technical infrastructure, as delivering multimedia content requires reliable internet connectivity and access to suitable hardware and software. Limited internet bandwidth, outdated technology, and technical glitches may impede students' access to the modules and hinder their learning experience (37). Hence, educational institutions must ensure ample technical support and resources for a seamless online learning environment. Maintaining student engagement is challenging in online modules compared to traditional classrooms, where instructors can directly interact with students and gauge their level of engagement, without relying on students' self-directed learning (38). There is a risk that students will passively consume content without active participation or deep comprehension in online modules. Therefore, establishing regular communication channels, such as discussion forums or live virtual sessions, is important to facilitate interaction and collaboration among students and instructors. Furthermore, the implementation of interactive online modules may demand significant resource allocation in terms of time, funding, and expertise for sustainability. Developing high-quality multimedia content, maintaining online platforms, and providing technical support necessitate substantial investment. Educational institutions must ensure sufficient funding and resource allocation to create and sustain interactive online modules effectively. Collaboration among instructional designers, multimedia experts, and subject matter experts is crucial to produce engaging and effective modules (27). In addition, ongoing maintenance and updates are necessary to align with technological and pedagogical advancements.

CONCLUSION

This article provides a roadmap by applying Gagne's Nine Events of Instruction as a framework for designing interactive online modules as a supplemental tool in the teaching of dental materials science. Through these interactive modules, it can be postulated that students will develop a deeper understanding of dental materials and their clinical applications. With careful development and implementation, the online modules can offer promising avenues to effectively support traditional teaching methods and improve student learning outcomes. However, it is important to address challenges related to technology, student engagement, and faculty development programmes. By adhering to best practices, continually evaluating effectiveness, and considering ethical considerations, educators can successfully integrate interactive online modules into the existing curriculum, thereby fostering an enriched learning experience for students. Ultimately, this will empower future healthcare professionals with the knowledge and skills necessary to excel in their clinical practice.

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