Received: 7 June 2020 | Revised: 10 August 2020 | Accepted: 11 August 2020

DOI: 10.1111/eje.12595

COMMENTARY

WILEY

Defining dental operative skills curricula: An ADEE consensus paper

James Field[1,2] | Jonathan Dixon[2] | Ashley Towers[2] | Rachel Green[3] | Hathal Albagami[2] | Guy Lambourn[4] | Julie Mallinson[5] | Wietske Fokkinga[6] | Jorge Tricio-Pesce[7] | Tin Crnić[8] | Sibylle Vital[9]

[1]Cardiff University, Cardiff, UK

[2]The University of Sheffield, Sheffield, UK

[3]Newcastle University, Newcastle upon Tyne, UK

[4]The University of Plymouth, Plymouth, UK

[5]The University of Bristol, Bristol, UK

[6]Medical Centre Nijmegen, Nijmegen, The Netherlands

[7]Universidad de los Andes, Santiago, Chile

[8]EDSA, Dublin, Ireland

[9]Paris Descartes Universite, Paris, France

Correspondence
James Field, Cardiff University, Cardiff, UK.
Email: fieldj2@cardiff.ac.uk

Abstract

This paper reports on the recent activity of the pan-European consensus of the ADEE Special Interest Group for Pre-Clinical Operative Skills. Following the previous recommendations from the group, and in order to support teachers and to harmonise the delivery of skills training across Europe, a more formal curriculum relating to pre-clinical operative skills needs to be created. This paper reports European consensus surrounding the categorisation (level of importance, and difficulty) of basic operative dental clinical skills within the undergraduate curriculum and provides recommendations relating to session structure and timing of curricular elements for basic operative dental clinical skills teaching.

KEYWORDS

clinical skills, consensus, curriculum, dental, pre-operative

1 | BACKGROUND

During the annual Association for Dental Education in Europe (ADEE) meetings in 2015, 2018 and 2019, a series of Special Interest Group sessions focussed on the teaching of pre-clinical operative skills. The first year, following a pan-European survey, the group concluded that significant variation exists in curriculum structure, content and scope of practice across different institutions.[1] As a result, the group recommended that "Learning outcomes, teaching activities and assessment activities of pre-clinical skills should be shared collaboratively." Indeed, in order to support teachers and to harmonise the delivery of skills training across Europe, a more formal curriculum relating to pre-clinical operative skills needs to be created. This aspiration also complemented recommendations from the recently published "Graduating European Dentist" curriculum,[2] which also encouraged subject matter experts to collaborate and develop subject-level learning outcome-based curricula.

1.1 | Learning outcomes

Pre-operative clinical skills are extremely challenging, not just in terms of students acquiring new operative skills—but also by way of ensuring that students are well supported during a particularly stressful and intense period of their programme.[3] For the majority of students, the operative skills they are being tasked to learn are novel and difficult. Moreover, for each practical session, there is inevitably not one learning outcome but multiple learning outcomes that are assigned. For example, the students may be primarily learning how to operatively manage occlusal caries; and yet, we would also be expecting to reinforce other essential clinical skills, such as hand washing, or correct posture. It is likely that the students are engaged with multiple cycles at any one time. Further, more difficult learning outcomes may not be met within the session; it may require multiple sessions to move through the "larger" cycle. Learning how to work with other members of the dental team or learning peer review and

critical appraisal might be examples of this. It is therefore important for staff and students to understand the expected complexity of each task, at which points essential and straightforward skills are reinforced, and at what points difficult skills will be revisited and developed further. It is critical that expected learning outcomes for the session are pre-published and available to students, and that students are encouraged to raise concerns if they feel that they are failing to meet the expected learning outcomes as they progress through the course.

As a result of these emergent themes and discussions within the group, it was decided that a degree of consensus was required relating to curriculum content, but also levels of operative difficulty for various tasks. This, in turn, will help skills educators to plan their courses and individual sessions in a structured way, that is sensitive to the needs of their learners.

The aims of this paper were therefore to:

- report European consensus surrounding the categorisation (level of importance, and difficulty) of basic operative dental clinical skills within the undergraduate curriculum
- provide recommendations relating to session structure and timing of curricular elements for basic operative dental clinical skills teaching

2 | Methods

Developing consensus consisted of two methodological components, in keeping with Kern's model of curriculum development[4]; a scoping questionnaire (in order to formulate intended learning outcomes) and a panel discussion with pan-European skills educators (to discuss implementation and instruction strategies).

Regarding the questionnaire, a request to complete an online questionnaire, in English, was sent electronically to skills leads at all ADEE member schools across Europe. The following information was collected in relation to basic operative skills:

- The level of importance within the curriculum (not important, essential, important or aspirational)
- The level of operative difficulty (easy, moderate, difficult)
- Whether the skills should be assessed prior to treating patients (yes, no)
- Free text about any *additional* basic operative skills that should be included

The questionnaire was piloted by a small working group from across Europe in order to test the face and content validity. Modifications to clarity of the English and understanding of the format were made after feedback from the initial appraisal. The definitive questionnaire was hosted by onlinesurveys.ac.uk and employed conditional entries, whereby participants were unable to submit without completing the necessary information. The link remained active for three months. The responses were exported as a PDF and used to inform discussion at the ADEE Special Interest Group on 22 August 2019 in Berlin, Germany, where open discussion helped to further develop consensus.

3 | Results

The initial survey was completed by 29 institutions, from 9 countries (Table 1). Following discussion of the findings at the Special Interest Group, basic operative skills were divided into:

- Essential skills that are classed as easy or moderately difficult (Table 2)
- Difficult and aspirational skills (Table 3)

Given the large number of basic operative skills that were discussed, the skills were also categorised within the tables into the following themes: Equipment and environment, Material application, Operative skills, Reflective practice, Communication and Team Working and Professionalism. The Special Interest Group discussion lasted for over 2 hours and it was clear that there were common challenges faced by dental skills educators. Reassuringly, the group was able to come together to suggest some strategies for maximising the learning within each skills session, and longitudinally across a skills course. A significant amount of time was also spent discussing:

- Generic session learning outcomes
- The need for regular reflection, critical appraisal and peer review
- The need for regular progress review and action planning during skills courses (ideally with a progress review scheduled every 4-6 weeks)
- The need for bricolage[5] (or purposeful play) with materials and equipment, in order to increase familiarity and develop confidence prior to using them for new operative procedures

Following the activities in Berlin, the authors devised a diagram which represents the learning journey longitudinally during a skills course, in an attempt to capture many of the important elements discussed. This is represented in Figure 1.

TABLE 1 Countries that responded to the initial questionnaire

England
France
Georgia
Germany
Hong Kong
Portugal
South Africa
Spain
United Kingdom
Wales

TABLE 2 Essential easy and moderately difficult, longitudinally taught tasks (E—essential, I—important)

Topic	Examples of bricolage, purposeful play, or further task deconstruction
Equipment and environment	
Identify basic operative equipment (E)	• Engaging with kit inventories or memory games • Explore how various pieces of equipment should be held in order to maximise efficiency
Demonstrate safe use of equipment (E)	• Delegate students' responsibility for their partner's clinical area • Empower students, tutors and nurses to issue "red cards" for unsafe practice, which then mediate a reflective discussion • Identify hazards and possible injuries within the clinical environment—and discuss how they might impact on the safety of patients and the dental team
Demonstrate effective use of personal protective equipment (PPE) (E)	• Practicing putting on gloves, masks and safety goggles • Demonstrate barriers to non-verbal communication when wearing masks and goggles—encouraging students to critically appraise each other's work whilst wearing PPE
Demonstrate effective zoning of the surgery (E)	• Delegate students responsibility for particular zones • Encourage a narrative around the use of space • Place edible items such as an apple into "clean" spaces and mediate discussion around their appeal post-operatively • Demonstrate the effects of aerosol and contact contamination by placing red dye into the water-line on a simulator unit—or see this demonstrated online by The Organization for Safety and Asepsis procedures foundation (https://www.osap.org/page/SDVEducatorsNonMbr)
Demonstrate effective hand washing (E)	• Use of indicator dyes such as Glitterbug® to determine effectiveness of handwashing
Effectively place dental dam (E)	• Explore the angle of application of dam forceps onto the clamp • Explore clamps visually around common areas of fatigue • Play with dental dam sheets, exploring elastic limits and tear resistance • Explore a range of techniques for application of dental dam including isolation of multiple teeth
Effectively place, and check the adaptation of, a matrix band (E)	• Practice assembling and disassembling bands • Discuss correct disposal and implications for sharps injuries • Explore the force required to displace bands • Explore the effects of different wedge types on band adaptation • Explore the approximal margins of restorations placed with and without an effectively adapted matrix band
Effectively carry out basic life support (E)	• Role play emergency scenarios within the cohort on a regular basis • Play memory games with the contents of the emergency drugs box
Material application	
Effectively mix and handle direct restorative materials (E)	• Explore how restorative materials behave during dispensation, mixing and application • Mixing and preparing materials for colleagues • Explore the impact of temperature on the setting time of materials • Explore the impact of artificial light on the working time of composite materials • Explore the thixotropic nature of composite resins by applying and adapting thin layers of material into a putty matrix
Safely apply topical fluoride to the teeth (E)	• Painting an even film of dye onto typodont teeth • Explore how aqueous contamination can complicate fluoride varnish application
Demonstrate effective enamel and dentine bonding (E)	• Explore selective and total etch techniques on sectioned teeth • Explore instruction sheets for bonding products and mediate discussion around bonding to different substrates • Demonstrate the effects of contaminating the surface of unset resins with bonding primers, water and Vaseline
Operative skills	
Accurately chart the dentition (E)	• Chart one-another's dentition • Peer review accuracy of charting • Play "charting Bingo" to familiarise students with the nomenclature
Demonstrate an effective finger rest (E)	• Practice following shape outlines on the bench whilst holding a handpiece, using a defined finger rest position • Explore a range of operator positions and appropriate finger rest positions in each arch • Discuss and peer monitor the use of a hard tissue finger rest instead of soft tissue support
Place and critically assess a fissure sealant (E)	• Practice application of the sealant to a range of surfaces, exploring surface adaptation and flow rate • Explore placed sealants with sharp probes and attempt to dislodge or remove

(Continues)

TABLE 2 (Continued)

Topic	Examples of bricolage, purposeful play, or further task deconstruction
Safely administer local infiltration anaesthetic (E)	• Explore anatomical landmarks and practice delivering anaesthetic using 3D models or within a virtual environment • Play card game (matching pairs) with anatomical structure and method of LA • Explore the equipment including safe setup and use of anaesthetic needles • Explore the pressure required to administer local anaesthetic (and the associated flow rates) into inanimate objects such as an orange • Practice operator and patient positions and narrate the route of the needle • Practice delivery on peers and discuss the experiences as a group
Manage occlusal carious lesions (E)	• Narrate the use of radiographic and clinical findings to estimate lesion depth • Discuss how the lesion will be accessed, including handpiece and bur types • Practice planning and then following cavity outlines, ensuring accuracy and consistent depth
Remove caries from the ADJ (E)	• Explore carious teeth, by sectioning sagittally, and identifying anatomical and pathological features • Discuss access to the ADJ • Narrate the types of instruments available to remove caries at the ADJ • Practice clearing the ADJ on carious natural teeth
Remove unsupported tooth tissue and refine preparations (E)	• Explore the use and correct application of chisels on natural and typodont teeth on the bench • Explore the impact of stones, discs and burs on the margins of preparations, including pressure and amount of tissue removed
Create suitable anterior and posterior approximal preparations (E)	• On the bench, explore the emergence position of pear shaped burs when used to remove carious tooth tissue beneath the contact point • Narrate the value of leaving a protective sliver of tooth tissue at the marginal ridge • Practice seating the bur at a defined starting position, using a well-controlled finger rest • Explore the impact of incorrect bur angulation and posture
Place effective anterior and posterior approximal restorations (E)	• Ask students to narrate the process of restoration from material placement to final finishing • Remove restored teeth from jaws and explore proximal contour and voids or excesses of material • Explore restoring teeth with and without the use of approximal wedges • Explore the effects of bulk placement of composite and the limitations of depth of cure • Explore colour changes in composite after curing • Blinded peer review and critical appraisal of approximal restorations
Finish and polish restorations appropriately (E)	• Explore the impact of polishing discs, strips and burs on composites and natural tooth tissue both in terms of material removal and heat generation • Explore how discs and strips alter or polish restorations, depending on their grit size • Explore how discs and strips can be revitalised by rinsing debris from their surface
Place and critically assess a direct temporary restoration (I)	• Explore the working time of temporary restorative materials on the bench • Explore the strength and resilience of temporary restorative materials in thin and thick section
Effectively use hand and ultrasonic scalers for supragingival scaling (E)	• Play "scaler tip" bingo in order to familiarise students with tip types • Draw large tooth diagrams and indicate which scaler tips should be used on each surface • Explore the sensation and efficacy of various scaler tips when applied at correct and incorrect contact angles • Explore the potential damaging effects of ultrasonic scalers on root dentine on the bench • Remove varnish from the crowns of typodont teeth using an appropriate finger rest • Remove simulated debris sub-gingivally from models, critically appraising the result before and after removal of the gingival mask
Obtain accurate upper and lower arch impressions (I)	• Explore how trays can be manipulated, adjusted and extended in order to fully support the impression material • Practice inserting the tray whilst maintaining control and retraction of the tissues • Explore different methods for loading and pre-loading material, and for seating the tray
Accurately record an intercuspal position (E)	• Explore the behaviour and accuracy of registration materials by recording surfaces of detailed object on the bench • Discuss the discrepancy in surface detail between silicone pastes and alginate impressions • Encourage students to take impressions on peers and articulate models themselves—then critically appraise the process, comparing clinically recorded contacts with those noticeable on the articulated models • Explore the border movements of the mandible (Posselt border movements) on peers
Fit and cement a preformed metal crown (E)	• Explore the safe use of Bebe/crown scissors including the effects they have on the margins of stainless steel • Practice holding positions whilst crowns are being adjusted with rotary handpieces and hand instruments • Practice the application of crimping sheers to ensure close fitting of the crown margins

(Continues)

TABLE 2 (Continued)

Topic	Examples of bricolage, purposeful play, or further task deconstruction
Demonstrate effective repair of existing direct restorations (I)	• Practice cutting retentive preparations into composite and amalgam blocks, exploring how the materials behave • Explore how major modifications to existing restorations will destabilise them and cause loss of retention • Use plaque disclosing solution to explore how sandblasting the surfaces of composite and amalgam—and treating with a silane coupling agent—can reduce microleakage
Perform non-surgical exodontia on models (I)	• Explore patient and operator positioning for optimal force application and operator postural health • Play instrument bingo in order to learn the names and applications of each hand instrument • Play card game (matching pairs) with hand instruments and tooth types
Reflective practice	
Demonstrate effective reflective dialogue (E)	• In groups, discuss the individual elements of critically reflective dialogue[18] • Encourage students to share experiences through story telling of what went well, what was hard and what went wrong • Encourage staff to contribute and mediate the stories to provide experiential context
Peer review one another's work (E)	• Practice engaging with peer review using non-dental topics that are more familiar—for example students might bake cakes or write a poem and then seek feedback from their colleagues
Critically appraise work against set criteria (E)	• Practice breaking down tasks into smaller components, which can each receive assessment and feedback • Mediate students grading and offering advice to one another based on set criteria
Identify faults with preparations and restorations (E)	• Demonstrate and narrate errors when preparing and restoring teeth • Encourage students to make purposeful mistakes with their work and then engage in peer review and peer dialogue.
Communication and team working	
Take an effective patient history (E)	• Role play with pre-prepared scripts before moving on to unaided history taking • Encourage students to make specific enquiries about defined parts of each other's lives and summarise to the group • Students should practice summarising a history that is told to them, rather than writing things down as the patient is speaking • Explore how closed or open questions can facilitate or hinder history taking • Discuss the impact of social and medical conditions on patients and the way in which this can determine the course of the discussion • Students should be encouraged to watch good and bad history taking examples and highlight important elements such as body language, eye contact, rapport, empathy and question style (these can be peer recordings)
Provide tailored oral hygiene, caries prevention, and dietary advice (E)	• Students should be encouraged to watch good and bad preventive advice examples and highlight important elements such as body language, eye contact, rapport, and engagement • Students should be encouraged to teach each other novel non-dental skills during a session, in order to develop skills explaining non-familiar concepts—such as playing an instrument or another practical skill
Professionalism	
Demonstrate punctuality and good presentation (E)	• Students to take turns to present the first 5 minutes' discussion of a practical skills session (aims, learning outcomes) (taking the tutor's role to start the session) • Encourage students to plan backwards from the session start time, allocating time to various necessary tasks • Encourage late students to share their reasons for being late (voluntarily) to the group, and mediate a discussion around attendance, punctuality and presentation
Demonstrate adequate preparation for the sessions (E)	• Mediate discussion at the end of each session about the next intended learning outcomes and requirements—this can be student-led • Mediate discussion at the start of each session that involves the whole group around topics that students should be familiar with
Demonstrate care/maintenance of equipment in the skills laboratory (I)	• Encourage students to sign equipment out and maintain an equipment inventory • Give student shared responsibility for equipment (between two students) • Award student professionalism grades based on their level of maintenance of equipment • Award students a mark for "soft tissue management" when working on phantom heads, which reflects the care taken with the cheeks • Encourage students to oil their own handpieces at the end of each session.

4 | Discussion

It is clear that there is huge disparity with the way in which operative skills sessions are organised and delivered across Europe, and indeed, the wider world. This is an indication of just how difficult it is to cater for the needs for a wide range of adult learners, presenting with a range of differing abilities and previous experiences—both practically, socially and emotionally. Nonetheless, the activities of

TABLE 3 Difficult and aspirational tasks that could be deconstructed, or employ bricolage with materials and equipment (E—essential, I—important, A—aspirational)

Topic	Examples of bricolage, purposeful play or further task deconstruction
Operative skills	
Undertake operative procedures within a mirror image (E)	• Draw simple shapes onto paper whilst working in a mirror image • Escape from a maze or join the dots on paper whilst working in a mirror image • For these tasks, a visual obstacle needs to be set up so that the paper is not visible by direct vision—usually this involves a colleague holding a piece of paper over the operator's hand • Consider using a purpose-made training device[19]
Establish an ergonomic working position (I)	• Demonstrate the lever functions of the operator and nursing chair including an ideal posture • Encourage students to monitor each other's posture and encourage feedback • Consider a formal session with an Alexander Technique (https://www.nhs.uk/conditions/alexander-technique/) • Ensure that students are placing light sources parallel to their line of direct sight • Encourage students to set out any necessary equipment before they begin their operative procedures, and maintain this in an orderly fashion
Develop handpiece control and indirect vision (E)	• Consider the use of virtual reality simulators to develop handpiece control skills • Consider the use of a "mock" handpiece[20] or home practice blocks[21]
Place an effective direct cusp replacement composite restoration (E)	• Use of wax to systematically build up cuspal form on study casts • Narration of each critical stage during demonstration of the procedure • Mediating discussion around the challenges and how to overcome these particularly in relation to marginal ridge anatomy, cusp form and occlusal morphology • Practice restoring cuspal form on the bench using the essential lines (or similar) concepts[22]
Effectively access and unroof the pulp space (E)	• Ask students to map out their anticipated access shape for a range of teeth on paper using outline diagrams • Encourage students to measure bur length in comparison to tooth length and narrate a discussion about the likely position of pulp spaces • Section teeth sagittally and compare bur length and position, highlighting then benefits of unroofing pulp horns in the first instance • Practice long axis orientation of the bur during preparation using blocks of plaster or acrylic—this can also be assessed accurately using VR simulation exercises • Explore use of the briault probe for detecting internal surface features by asking students to explore inside access cavities on the bench
Demonstrate effective placement and carving of dental amalgam (I)	• Explore the forces required to adequately condense amalgam, using easily dispensable objects such as Polo mints, or using 3-D printed models • Explore the changing handling characteristics of amalgam during the setting time including the optimal time to carve material away and remove matrices • Explore the limit of hand instrumentation in changing amalgam contour once the working time has been reached by working with hand instruments and amalgam on the bench • Encourage students to time their activities from the initial mix, noting the finite working time for amalgam
Effectively deliver nerve block anaesthesia (E) Effectively deliver supplemental local anaesthesia (pdl, intra osseous for example) (A)	• Explore the use of commercial models to demonstrate and narrate anatomy, positioning of self and equipment, aspiration, and delivery • Employ VR haptic systems to visualise the position of the needle in real time relative to other anatomical structures
Effectively prepare occlusal and approximal cavities on primary teeth (I)	• Encourage students to draw "caricature" images of primary teeth, narrating their exaggerated features compared to permanent teeth • Carry out approximal preparations without an adjacent tooth in the first instance, so students can explore bur positioning and emergence in relation to the greater bulbosity of primary tooth crown form
Undertake operative procedures using magnification (A)	• Mediate a discussion with students about the usefulness and application of magnification • Explore the setup and use of magnification on the bench, either with loupes or operating microscopes • Begin setup of focus and magnification, and exploration of settings based on an "x" drawn onto a piece of paper • Explore the impact on restricted focal distance and posture when using magnification

(Continues)

TABLE 3 (Continued)

Topic	Examples of bricolage, purposeful play or further task deconstruction
Report accurately on dental radiographs (I)	• Encourage students to learn mnemonics to approach radiograph reporting logically and consistently • Discuss with the students about the need to accurately describe the radiograph in written form • Explore with students the concept of reporting visual anomalies (ie radiopacities, radiolucencies) rather than pathologies • Encourage students to identify normal anatomical features on radiographs prior to describing anomalies
Undertake minor oral surgery (surgical removal of tooth/tooth roots) (A)	• Explore the anatomy of the surgical area using models, 3D prints or within the virtual environment • Explore the surgical kit and trial different instruments to note their effect (for example periosteal elevators) • Discuss the benefits of an aseptic technique • Practice gowning for an aseptic technique and managing a sterile working environment
Communication and team working	
Communicate with other professionals in a written format (I)	• Practice writing up laboratory and radiology request forms and prescriptions • Pass these to colleagues and ask for an explanation of what is being requested • Practice written referrals or communications with other medical professionals involved in patient care
Reflective practice and professionalism	
Critically reflect on each session (E)	• Encourage students to share experiences through story telling of what went well, what was hard and what went wrong • Encourage staff to contribute and mediate the stories to provide experiential context • Explore alternative actions through group discussion • Explore other frames of reference for those experiencing the event(s) perhaps by asking students to role play different team members and patients
Develop appropriate action plans to direct future learning (I)	• Encourage use of a worry tree during each session for students to post their feelings or perceived difficulties • Encourage students to set one or two learning objectives or action points for next time, based on a reflective dialogue of the session • Review the action points at the beginning of each session
Manage time and resources in an efficient manner (E)	• Encourage students to deconstruct complex tasks and allocate amounts of time for each component • Mediate discussion about the allocation of time and how to manage when stages take longer than expected • Encourage students to keep track of materials used and mediate discussion at the end of the session about material cost, sustainability and efficiency.

the Special Interest Group, in categorising the importance and level of difficulty of basic operative dental skills (Tables 2 and 3), and important elements in the learning journeys (Figure 1), have been hugely important. These exercises will allow skills course leads to rationalise their curricula, including the logistics of when and how particular skills are taught.

4.1 | Lesson planning

It was clear from group discussion that colleagues would value guidance on how to develop appropriate lesson plans for operative preclinical skills. Although there are several learning theories that can be applied to the teaching of operative clinical skills, the most appropriate within this context is undoubtedly that of experiential learning, described by Kolb.[6] Kolb's principles build on the previous work of Lewin[7] and Dewey[8]—here the suggestion is that learning is more than just the behavioural model of stimulus and response. There is a suggestion of higher-order thinking—taking into account immediate and past experiences, giving the learning situation context and personal meaning whilst working towards a desired goal. These processes form a "learning cycle" through which the learner transitions on their educational journey. Table 4 outlines how a student might progress through a learning cycle within a pre-clinical skills session.

The learning cycle is a useful concept in that it can accommodate a range of learning styles[9]—self-directed, practical and problem-based. As skills teachers, we are therefore able to plan for the session effectively—and the recommendation is that we ensure that learners pass through each learning stage.[10] Whilst it is often assumed that learners should begin with "active experimentation"—as skills educators, we should be prepared to deliver sessions that start students off in different learning states, in order to maximise their educational experience. This might be by asking students to:

- recall theories and knowledge prior to beginning the practical element;
- review previous experiences and performance prior to beginning further work;
- begin a new practical task with clear goals, but little direct

practical instruction.

The latter by its very nature provides an excellent opportunity for problem-based learning (PBL). The way in which this applies to healthcare simulation is eloquently discussed by Russel Jones.[11] It is not appropriate to use this approach for all clinical skills sessions, but it is widely understood that "learners who commence by focussing on a problem before attempting to understand the underlying principles, have equal or greater success than learners using a traditional approach."[11] That said, it is imperative that students undertaking PBL for operative clinical skills have a clear goal in mind, before embarking on their problem-solving journey.

4.2 | Cognitive load

Given that these experiential learning processes are based on context and constructivism, we would argue it appropriate that the learning cycle is considered as a learning *spiral*, which develops over time (and over consecutive sessions). It could be argued that each learning outcome should have an individual and defined learning cycle. However, it is ontologically questionable to try and separate out these experiences; learning experiences will undoubtedly follow on from previous ones and, as such, the cycle becomes more dynamic. As educators, we should also be encouraging students to reflect on their experiences—and in theory, students should be capable of reflecting *on* and *in* action.[12] However, the degree to which this is possible will largely depend on the *cognitive load*[13] of the session, and the number of times a student has been through their experiential cycle. One example is trying an intricate practical skill for the first time—it may be so difficult and have so many elements to consider simultaneously (the intrinsic cognitive load) that the individual undergoes no other conscious thought process than *doing*; this leaves little or no cognitive capacity for the germane cognitive load necessary for learning. They can later reflect *on action*. At subsequent attempts, the individual may be able to reflect *in action* as schemas are constructed and automated for the task[14] and the cognitive load is reduced. The extraneous load of learning complex operative skills can be reduced by either:

- being taught longitudinally
- being broken down into more manageable, easier tasks or
- a combination of both approaches

This will reduce the cumulative cognitive load for the task, freeing up cognitive resource for more efficient learning. Whilst it is not within the scope of this paper to discuss the intricacies of individual session timetabling, educators should also be mindful of the critical nature of "cognitive downtime" through appropriate periods of rest and sleep during skills training, in improving academic performance and motor skill learning.[15,16] With these aspects in mind, the activity of the Special Interest Group in detailing how operative tasks can be deconstructed, or purposeful play (bricolage) used in order to familiarise students with peripheral elements of tasks, is therefore of paramount value.

4.3 | Practical implications

Traditionally operative skills courses begin by teaching the least invasive, least destructive skills first—and by teaching procedures in full; from the start to the intended clinical endpoint. It is also common for programmes to provide both a basic and more advanced

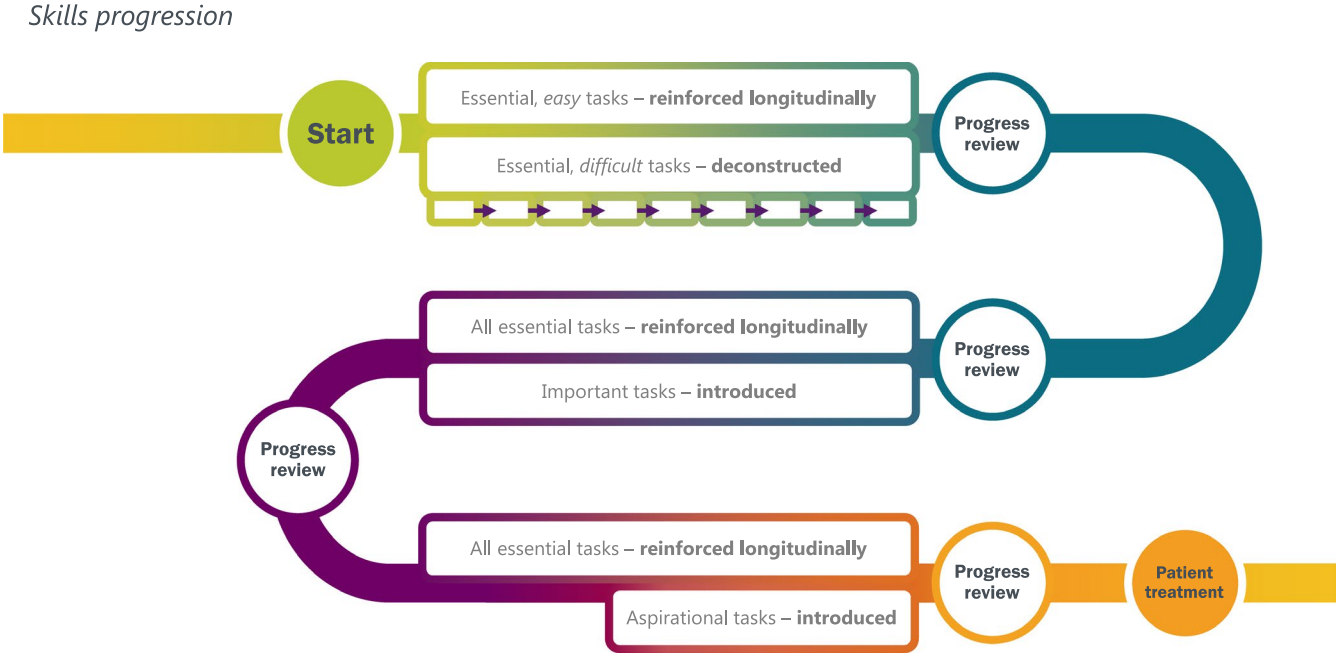

FIGURE 1 The longitudinal learning journey through a pre-clinical operative skills course [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 4 How a student might progress through a learning cycle within a clinical skills session, based on Schön's reflective cycle[12]

Concrete experience (do)	The student attempts to carry out the practical exercise. They will be encouraged to critically appraise their work, based on a set of assessment criteria or teaching aids. They will also appraise the work of their colleagues and as a wider group. This process will allow them to objectively assess what they have achieved, or what has *actually* happened.
Reflective observation (review)	It is likely at this stage that the student has started to think about their own personal experience of the exercise. They may reflect on the outcome and break the experience down into smaller stages. Some things may have gone well; others not. They may have found certain aspects harder than others, or they may have not been able to achieve what they wanted. The student will then discuss the experience with a colleague and the wider group.
Abstract conceptualisation (theorise)	In reflecting and discussing the experience, the student may begin to think about how they could remedy or improve on any problems that they encountered. They may also find solutions or reassurance by talking to their peers and tutors. This will lead to the construction of a new approach, or a new "plan" that they should be keen to try.
Active experimentation (apply)	The student will then have the opportunity to try the exercise again. However, on this occasion, the student is approaching the exercise with a certain amount of direct experience on which they have reflected. They may have developed a new approach, or appreciate the exercise in a different light. The latter may not be immediately obvious to the student. Once the exercise is complete, they will begin the cycle again; reviewing their second attempt.

skills courses as students progress through their studies. It is assumed that these strategies provide an optimal pathway for learning progression, but there is little evidence that this is indeed the case. Further, often practical skills are developed throughout the degree programme via isolated courses from differing disciplines. In this way, it is not always clear what has been taught and when, between subject areas. This can make signposting more challenging for educators.

It could be argued that there is more value in deriving "common" skills across multiple procedures and disciplines, and choosing operative skills which develop and nurture these in a logical fashion. Looking more objectively to deconstruct operative procedures, and developing a "skills inventory," will provide an opportunity for improved efficiency of learning. It would also provide an opportunity for common skills to be longitudinally reinforced and assessed—meaning that as skills become increasingly complex, it is easier for students and their educators to determine where learning problems are occurring and to develop suitable tailored interventions. In order for this strategy to be successful, it is important for students to be aware of the learning outcomes both in advance, and during the session and the authors would recommend this strategy. By highlighting anticipated learning cycles for each session, students can be encouraged to engage in targeted discussions with their peers and tutors at every stage of the learning process. This facilitates and signposts the important concepts of feedback, critical appraisal and peer review.

The concept of bricolage and purposeful play is also critical in improving the efficiency of operative skills learning. There are commonalities across materials and equipment in terms of their manipulation and use, which can be exploited in order to reduce cognitive load and support the concept of productive failure. Here, there are resource implications in drawing together disciplines, and creating time for students to "play"—and the principle benefit here are in creating a supportive environment for “failure,” both in terms of students developing their own solutions and strategies, but also in providing opportunity to appropriately train faculty members to teach operative procedures effectively. The concept of nurturing risk and negotiating errors is explored by John Hattie, who highlights the educational benefits in terms of performance.[17] Some technologies allow close replication of the clinical environment, or the use of mobile models within the usual clinical environment, to reduce the “shock of practice” effect especially in relation to delivering local anaesthetics and exodontia—and this is an increasingly important strategy.

Tables 2 and 3 detail the early work of the Special Interest Group in deconstructing operative skills tasks and providing useful examples for bricolage and purposeful play in order to reduce the cognitive load that students may experience. These should act as a very useful basis for skills teachers to develop their own local skills inventories within their own schools or institutions.

4.4 | Conclusions/Recommendations

It became apparent through discussions within the Special Interest Group that simply defining the expected learning outcomes for skills courses was not enough. Educators reported that teaching pre-operative clinical skills was extremely challenging, not just in terms of students acquiring new operative skills—but also by way of ensuring that students were well supported during a particularly stressful and intense period of their programme. As such we, as educators, should be mindful of how we plan our skills sessions, and how our students are expected to develop as curious, independent learners, whilst being able to take risks and make mistakes within a safe learning environment. The Special Interest Group through ADEE has deconstructed a number of operative skills tasks and provided useful examples for bricolage and purposeful play in order to reduce the cognitive load that students may experience. These should act as a very useful basis for skills teachers to develop their own local skills inventories within their own schools or institutions.

The Special Interest Group also makes the following recommendations for consideration when planning or reviewing operative skills courses:

- Educators should consider whether to plan skills sessions in relation to deconstructed skills development rather than clinical presentation and complexity.
- Actual and abstract tasks should be planned logically and reinforced longitudinally through the programme.
- Educators should employ and co-create resources with students that break down difficult tasks.
- Longitudinal skills courses that teach students from multiple disciplines should be considered, rather than basic and advanced courses isolated to specific programmes.

ACKNOWLEDGEMENTS

The activity of this Special Interest Group was coordinated through the Association for Dental Education in Europe (ADEE). Special thanks are extended to EDSA, the European Dental Students' Association for their involvement in the consensus workshop and the authorship of this paper.

DATA AVAILABILITY STATEMENT

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

ORCID

James Field https://orcid.org/0000-0002-5462-4156
Jonathan Dixon https://orcid.org/0000-0002-3499-175X
Ashley Towers https://orcid.org/0000-0002-2711-1160
Jorge Tricio-Pesce https://orcid.org/0000-0002-2364-9828

REFERENCES

1. Field JC, Stone S, Orsini C, et al. Curriculum content and assessment of pre-clinical dental skills: a survey of undergraduate dental education in Europe. *Eur J Dent Educ*. 2017;22(2):122-127.
2. Field JC, Cowpe JG, Walmsley AD. The graduating European dentist: A new undergraduate curriculum framework. *Eur J Dent Educ*. 2017;21(S1):2-10.
3. Ersan N, Dölekoğlu S, Fişekçioğlu E, İlgüy M, Oktay İ. Perceived sources and levels of stress, general self-efficacy and coping strategies in preclinical dental students. *Pyschol Health Med*. 2018;23(5):567-577.
4. Kern D. *Curriculum Development for Medical Education*. Baltimore: The Johns Hopkins University Press; 2009.
5. Field JC, Walmsley AD, Paganelli C, et al. The graduating European dentist: contemporaneous methods of teaching, learning and assessment in dental undergraduate education. *Eur J Dent Educ*. 2017;21(Suppl 1):28-35.
6. Kolb D. (1984) *Experiential Learning: Experience as the Source of Learning and Development*. Englewood Cliffs, NJ: Prentice-Hall.
7. Lewin K. Action research and minority problems. In: Lewin GW, Allport G, eds. *Resolving Social Conflicts. Selected Papers on Group Dynamics*. New York: Harper & Brothers; 1957:201-216.
8. Dewey J. *Experience and Education*. New York: MacMillan; 1938.
9. Raschick M, Maypole DE, Day PA. Improving education through Kolb's learning theory. *J Social Work Educ*. 1998;34:31-42.
10. Healey M, Jenkins A. Kolb's experiential learning theory and its application in geography in higher education. *J Geogr*. 2000;99:185-195.
11. Jones R. Problem-based learning for simulation in healthcare. In: Riley R, ed. *Manual of Simulation in Healthcare*. Oxford University Press; 2008:213-225.
12. Schön D. *The Reflective Practitioner: How Professionals Think in Action*. New York, NY: Basic Books; 1983.
13. Sweller J. Cognitive load during problem solving: effects on learning. *Cogn Sci*. 1988;12:257-285.
14. Van Merriënboer JJG, Sweller J. Cognitive load theory in health professional education: design principles and strategies. *Med Educ*. 2010;44(1):85-93.
15. Okano K, Kaczmarzyk JR, Dave N, et al. Sleep quality, duration, and consistency are associated with better academic performance in college students. *npj Sci Learn*. 2019;4:16.
16. Walker MP, Brakefield T, Seidman J, Morgan A, Hobson JA, Stickgold R. Sleep and the time course of motor skill learning. *Learn Mem*. 2003;10(4):275-284. https://doi.org/10.1101/lm.58503
17. Hattie J. Chapter 7: The flow of the lesson: the place of feedback. *Visible Learning for Teachers: Maximising Impact on Learning*. Routledge; 2012:139-140.
18. Field J, Vernazza C. Developing a grading matrix for reflection. *Med Educ*. 2013;47:531.
19. Rau G, Rau A. Training device for dental students to practice mirror-inverted movements. *J Dent Educ*. 2011;75(9):1280-1284.
20. Seeballuck C (2019) Dental M.U.M.S., unusual pens and the challenges of invention. ADEE Free Stage session, ADEE Annual Conference 2019, Presented 22/08/19 09:45.
21. Lugassy D, Levanon Y, Shpack N, et al. An interventional study for improving the manual dexterity of dentistry students. *PLoS One*. 2019;14(2):e0211639. https://doi.org/10.1371/journal.pone.0211639
22. Chiodera G (2018) Essential lines. https://www.styleitaliano.org/essential-lines/. Accessed March 20, 2020.

How to cite this article: Field J, Dixon J, Towers A, et al. Defining dental operative skills curricula: An ADEE consensus paper. *Eur J Dent Educ*. 2021;25:405–414. https://doi.org/10.1111/eje.12595