Primer on Preclinical Instruction and Evaluation

Anna Marie Hauser, R.D.H., M.B.A.; Denise M. Bowen, R.D.H., M.S.

Abstract: This review summarizes the available literature for both instruction and evaluation of the novice dental and dental hygiene preclinical student. Effective instruction for dental and dental hygiene instrumentation requires knowledge of motor skills theory and mechanisms of fine motor skills attainment. The novice learner requires small, explicit steps that clearly define production. Prior to any performance, the skill to be performed should be envisioned accurately by the learner. Timely, precise feedback from the instructor to the learner contributes to learning. Novices are unable to judge their performance accurately, so self-assessment skills must be taught. Repetition enhances motor performance. Instruction is supported through well-designed evaluation instruments containing explicit criteria arranged in the correct order of production. Assessment tools should be designed to aid in providing specific, immediate feedback. Well-designed assessments may also aid in calibration of instructors. Examples of evaluation instruments are found in the literature, and several are reviewed in this article. For those responsible for preclinical performance assessment, application of current motor skills theory and development of appropriate instruction and evaluation instruments may result in improved student performance. Studies also indicate the instructional environment in the dental clinical setting may be less stressful if evaluation is based on achievement of target levels rather than multiple daily grades.

Prof. Hauser is Assistant Professor, and Prof. Bowen is Professor—both in the Department of Dental Hygiene, Idaho State University. Direct correspondence and requests for reprints to Prof. Anna Marie Hauser, Idaho State University, Department of Dental Hygiene, 921 South 8th Avenue, Stop 8048, Pocatello, ID 83209-8048; 208-282-6144 phone; 208-282-4071 fax; hausanna@isu.edu.

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Learning fine motor skills is requisite for learning dental and dental hygiene instrumentation and is challenging for students. Successful instruction of novice preclinical learners requires knowledge of motor skills acquisition and application of effective evaluation mechanisms. This review of the literature summarizes published information from PubMed and CINAHL related to motor skills training theory, applications to health professions education emphasizing preclinical dental and dental hygiene instrumentation, and development of appropriate assessment tools for evaluation of preclinical dental or dental hygiene students. The purpose is to present related information for oral health educators. This type of review would serve as an excellent resource for new preclinical course directors.

Motor Skills Theory

Motor skills theory defines a motor skill as a skill primarily determined by quality of movement produced by the performer. The concepts of motor performance and motor learning, although difficult to distinguish, are central to this theory. Motor performance is an observable attempt to perform a motor task. It is influenced by such factors as stress, fatigue, and motivation. Motor learning involves changes in an individual’s internal processes that determine that person’s capability to perform a motor task. Improvement in performance capability requires practice and repetition and represents the person’s level of learning. A connection between motor performance and motor learning involves the concept of implicit learning and the schema of learning stages. Implicit learning is defined as the process by which a learner improves performance through practice until the correct performance of the motor skill becomes automatic. Fitts and Posner describe early learning stages as cognitive (trial and error) and associative (targeted) and the later stage of learning as autonomous (free and easy). Preclinical performance would be categorized as cognitive and characterized by inaccuracy, inconsistency, hesitation, indecision, and a lack of confidence. Even with correct performance,
novices are not sure how they did it. Depending on the individual learner’s capabilities, motivation, and practice, as well as the difficulty of the motor skill, performance eventually becomes more accurate and consistent. This accomplishment is indicative of the associative stage. Only after significant and repeated experiences do some learners reach the autonomous stage characterized by automatic performance of the motor skill. Chambers used motor skills theory as a basis for describing the continuum of learning related to competency-based education. These learning stages are novice, beginner, competent, proficient, and expert (see Table 1).

Successful performance of intraoral procedures requires that dental and dental hygiene students attain a high level of fine motor control. Application of related theory and valid research findings should be considered when designing dental curricula for motor skills attainment. A four-part faculty development series published in the 1990s employed principles of motor skills theory to design effective strategies for preclinical instruction for psychomotor skills (see Table 2). In this series, the authors recommend beginning with an analysis phase followed by design and evaluation phases to create learning materials for motor skills training. Prior to designing any instruction, the performance to be completed is analyzed. Appropriate methods of teaching are identified, detailed steps are arranged in sequence, common mistakes are identified, and, finally, learning activities are created for each step. Novice students benefit from discrimination learning, that is, learning characteristics of a desirable product or skill by contrasting what is correct to what is not. Before beginning any task production, the novice should recognize ideal end results. In the evaluation phase, trials of the instructional modality are conducted with the students using the training exercises. The final test of success is to modify the instruction as necessary based on outcomes of the trials.

Novice Learners and Applicable Feedback

First-year dental and dental hygiene students are novice learners in the initial stage of the competency continuum as defined by Chambers and Glassman. As novices, these students are dependent on instructors and appreciate detailed directions with small steps. A novice student requires immediate and precise feedback. Novices learn to become competent in different ways than do beginners or students who are becoming competent. Design of appropriate motor skills instruction for preclinic will be more successful if these characteristics of the novice learner are recognized. In research designed to differentiate beginners from competent students based on their preclinical performance, Chambers and Geissberger

Table 1. Stages of motor learning and competency

<table>
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<tr>
<th>Stages of Motor Learning</th>
<th>Stages of Competence</th>
<th>Attributes</th>
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<tbody>
<tr>
<td>Cognitive (trial and error)</td>
<td>Novice</td>
<td>Requires explicit directions, small steps, standardized or ideal circumstances, slow, stiff or rigid, hesitant, extrinsic feedback, rules, dependence on faculty, isolated skills to provide foundation for later performance</td>
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<tr>
<td>Associative (targeted)</td>
<td>Beginner</td>
<td>Application of what has been learned, some judgment and recognition of need to adjust rules, guided performance, shows some initiative, extrinsically rewarded, semiconscious</td>
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<td></td>
<td>Competent</td>
<td>Ready to begin independent practice, has a range of judgment and procedures, capacity to accurately self-assess, understand what they are doing, conscious</td>
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<td></td>
<td>Proficient</td>
<td>Flawless, fluid, easily modified, conforms to context, intrinsically rewarded, appropriate values are internalized</td>
</tr>
<tr>
<td></td>
<td>Expert</td>
<td>Has internalized standards, is self-managed, performance is accurate and integrated, semiconscious (automatic), intrinsically rewarded</td>
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found that, when preparing Class II cavity preparations, both groups achieved basically the same end result of clinically acceptable preparations; however, during performance, beginners spent significantly more time in activities with no direct function to the cavity preparation. As a result of their inexperience, novices were not as effective in their operations and spent much more time refining the preparation than did the competent students. These findings support research related to the novice-to-expert continuum with evidence that novice-beginners are rule-driven and dependent on feedback because they are unable to judge their own effort during the performance. The role of the instructor needs to be that of a manager and an educational diagnostician of students’ learning. With knowledge of the evidence-based approach to successfully teach novices, instructors can design appropriate instruction and evaluation.

Specific and timely feedback about the skill performance contributes significantly to novice students’ attainment of a new skill. Following an extensive literature search of general, social science, and medical education literature for definitions of feedback, Van de Ridder et al. proposed an operational definition of feedback to be the following: “specific information about the comparison between a trainee’s observed performance and a standard, given with the intent to improve the trainee’s performance.” However, the novice student may actually be overwhelmed by constant feedback, yet at the same time become dependent on this feedback. Results of this study led the researchers to recommend that if novices train with VR systems, this learning should be supplemented with instructor support. In a subsequent study, two groups of novice dental students (n=12 for each group) did receive instructor support with VR feedback. One group learned with constant (100 percent) VR feedback; a second group learned under intermittent (66 percent) feedback; the control group (n=12) received no VR feedback or instructor support. Both feedback groups performed better than the control group (p<0.05). Interestingly, no significant differences were found between the two experimental groups receiving instructor support. Applicable feedback from faculty was identified as the variable impacting learning rather than the frequency of VR feedback. Barata and Schoen compared two instructional methods for teaching periodontal instrumentation to preclinical dental hygiene students: simulation feedback (n=23) versus a guided discovery approach (n=23). Results indicated the system providing immediate feedback was more successful (p=0.001). Specific and immediate feedback augments psychomotor skill attainment for the novice learner.

**Recognition Skills Training**

Acquiring noncognitive psychomotor control requires initial experiences closely matching future skills or recognition skills training. Performance is enhanced when the learning situation closely

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**Table 2. Application of instructional engineering principles in designing preclinical instruction for psychomotor skills**

<table>
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<tr>
<th>Analysis Phase</th>
<th>Begin by considering the final test. The instructor begins with knowledge of what the student will perform to demonstrate competence.</th>
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<tr>
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<td>Identify tasks and products pertinent to the final test.</td>
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<td></td>
<td>Analyze procedures, information, criteria, and task performance.</td>
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<tr>
<td>Design Phase</td>
<td>Identify suitable teaching and learning approaches including discrimination training.</td>
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<td>Order skills identified in the analysis phase. Identify common mistakes.</td>
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<td></td>
<td>Plan learning exercises for each skill component.</td>
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<tr>
<td>Evaluation Phase</td>
<td>Carry out trials and conduct formative evaluation.</td>
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<td>Make necessary modifications as determined from student performance.</td>
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Resembles the application conditions. Knight et al. analyzed success of a unit of a conservative restorations course redesigned to address one component of motor skills theory by teaching recognition skills to first-year dental students (N=86). Significant improvement (p<0.03) in product scores from pretest to posttest for Class I amalgam preparations was found. As a result of this study, the researchers suggested that, early in training, more time should be devoted to development of recognition skills than in production tasks. Applying these concepts from motor skills acquisition theory, Knight and Guenzel taught mirror use skills to an experimental group of dental students (n=92) and found that students in the experimental group were significantly more successful with indirect vision skills in preclinical evaluation of a dental preparation than the control group (n=25) who had not been taught mirror use. Similar findings were evident in an earlier study conducted by these same researchers. That study used drawings, model, and evaluation criteria including typical errors for recognition training to teach discrimination skills for waxing projects to a small sample of remedial dental students and a control group. The experimental group (n=6) receiving the training exhibited higher performance on waxing skills than the control group (n=7) not taught recognition and discrimination skills (p=0.0001). Feil et al. studied the instructional strategy of “leadup” exercises in which an experimental group of dental students in an operative course were taught discrimination skills regarding lengths, widths, and angles prior to Class II inlay, MOD amalgam, and MOD onlay preparation. The experimental group (n=25) significantly outperformed (p<0.05) the control group (n=25) on Class II inlay and MOD amalgam preparations. Interestingly, in this study, transfer of learning was inhibited for the MOD onlay. These researchers concluded beginning students were not able to successfully transfer skills because transfer of training is highly specific; the leadup experience for the MOD onlay had not been simulated; and features of an onlay preparation differed significantly from the Class II preparations. In an article discussing issues in transferring preclinical skills to the provision of patient care in clinic, Chambers noted an important determinant of skill transfer is overlearning—continuing to practice after correct performance is demonstrated. He recommended teaching fewer skills in preclinical courses and emphasizing continued practice of vital abilities in order to more successfully transfer skills to future ability of provision of clinical patient care.

Requiring students to view expert performance or product before learning the skill is an effective instructional technique. In a study published in 2008, Aragon and Zibrowski found that dental students (n=55) in a fixed prosthodontics course who were exposed to a video of a step-by-step expert demonstration of preparation of a tooth for an all-ceramic restoration performed significantly better (p=0.01) in comparison to the previous year’s class (n=52) not shown the video. The dental students who viewed the expert video also improved their performance as compared with their own scores on two other practical exams with no supplementary teaching aids. Curtis et al. used expert models to teach students in preclinical prosthodontics laboratory accurate self-assessment and improve performance on setting maxillary denture teeth on a model. These researchers provided second-year dental students (N=77) with photographs of ideal set-ups accompanied by specific criteria and followed by two consecutive simulation examinations and two self-assessments. Although the results indicated no significant increases in exam or student self-assessment scores, regression analysis indicated that improvement in student self-assessment predicted improvement in exam scores. The correlation of exams with student self-assessment scores increased from r=0.225 to 0.370. In a study of first-year family medicine residents, Hodges et al. videotaped medical residents (N=24) interviewing a standardized patient. The residents then viewed four interviews ranging from highly competent interviewer ability to incompetent interviewer ability and subsequently re-rated their own performance. Residents in the highest performance group were more accurate in self-assessment than the lowest performers. Self-assessment is well established in the literature as contributing to active learning. Reflection on personal accomplishments is vital for lifelong learning and is an important skill for the novice learner to begin to achieve. Students who learn recognition skills and can visualize successful performance prior to beginning may improve in quality of production. When constructive feedback is given immediately and is of high quality, the learner can improve self-assessment ability. Feil and Gatti videotaped eleven subjects as they completed an amalgam preparation on a plastic molar tooth in a manikin. To compare preclinical or novice performance to proficient or expert, the sample consisted of five dental students who had completed one preclinical operative course, one student beginning the third year, one student...
beginning the fourth year, and four instructors with clinical experience. While watching the videos of their own work, subjects subsequently gave self-reports of mental processes that occurred during the videotaping. Findings indicated novices conscientiously planned a desired performance prior to production while experts did not.\(^1\) Awareness of the desired outcomes, desired performance, knowledge of results, and knowledge of performance are four constructs that explain dental motor performance. The desired outcome is used to generate knowledge of results by comparing the mental processes with the product throughout production. This process results in interruptions during motor performance for the novice and not for the expert faculty member with clinical experience. Because accuracy of self-evaluation is closely related to successful outcomes, Feil and Gatti recommended a portion of the grade for any project reflect self-assessment skills.\(^2\)

### Evaluation Instruments/Student Performance Measures

Applying motor skills theory as well as subsequent conceptual models of learning stages to the development of effective evaluation instruments for novice learners may contribute to student learning. Motor performance of skills such as dental and dental hygiene instrumentation is always observable and is mastered at different stages of learning. In the early stages, the novice requires explicit directions, small detailed steps, and extrinsic faculty feedback and performs isolated skills under standardized or ideal circumstances. Execution also is cognitive as the beginner consciously considers each movement while performing and practicing the skill. Assessment should embrace these characteristics, and evaluation instruments need to be designed with specific criteria detailing performance standards. The level of a student’s performance is influenced by temporary factors such as fatigue, anxiety, motivation, attentional focus, and physical condition.\(^1\)

In 2003, Williams et al. reviewed the literature on assessment to explore cognitive, social, and environmental factors that may affect or bias performance evaluations. Although this review focused on the clinical competence of medical students and offered several recommendations for assessment of clinical competence, the majority of its findings are relevant to designing an environment and evaluation instruments for preclinical experiences. Novices’ performance is affected by external factors. The assessment tool used while observing motor performance must accurately measure the behavior being observed. Rating instruments should be brief, and feedback should be immediate and interactive. Formal observation should be coupled with inconspicuous observation of student performance. Raters should be trained and comfortable with the rating form. Assessment ratings by several different instructors serve to balance individual differences.\(^2\) With an understanding of cognitive, social, and environmental factors that may influence clinical performance ratings, instructors of dental and dental hygiene clinics may design activities and assessments that are effective in successfully guiding the novice student to competence.

### Valid Criteria, Rubrics, and Rating Scales

Several examples in the literature describe development, implementation, and validation of successful assessment schemes. An important aspect of these assessments is the development of explicit and meaningful criteria. Knight suggested that criteria be 1) valid: individually, collectively, and non-compensatory (independent of one another), and 2) reliable: all criteria accompanied with specifically described tests and levels of performance clearly defined in a matrix format.\(^2\) Criteria must clearly define levels of performance; therefore, the number of levels is confined to those that can be clearly delineated. Knight revised original evaluation forms to include very specific descriptors and limited the levels to excellent, clinically acceptable, and criterion not met to enhance training of students and faculty members, as well as inter- and intrarater agreement. Results of the pilot study of these instruments indicated that preclinical faculty members using instructional strategies for novice students to evaluate motor performance outperformed faculty members whose primary teaching responsibility was clinical. Preclinical instructional design is based on the premise that a student must know exactly what it is that is to be achieved in order to perform a designated procedure. Because practice enhances novice learners’ performance, evaluations should be repeated, and learners should receive feedback comparing their performance to ideal.\(^2\) Based on these recommendations by Knight, Haj-Ali and Feil developed grade forms with relevant criteria for each of three levels (ideal, acceptable, standard not
met) for preclinical Class II amalgam preparations. This assessment tool was then used for three tests of nine preclinical operative lab instructors who independently evaluated ten prepared teeth. The first test was conducted prior to calibration training. The second test was administered immediately after training, and the third test was given ten weeks later. Results indicated improvement in percent agreement with the gold standard was attained and preserved after ten weeks. Calibration of instructors is important especially for novice preclinical students who benefit from precise knowledge of results and accurate scores that reflect that assessment.

Criteria may be organized into a matrix format with standards clearly specified and each criterion expanded into written statements describing different degrees of quality. These rubrics allow evaluators to specify criteria related to each step in a clinical performance task and define each level of attainment on a continuum. Recently, Licari et al. published an excellent guide for developing evaluation forms both for preclinical and clinical performance and reaffirmed the importance of clearly defined criteria well organized in an evaluation form. They suggested that consistent terminology and a standardized format for all assessment forms were important both for the learner and the clinical instructors. Appropriate organization of the evaluation forms can facilitate provision of specific feedback and support active participation of the learner.

In their series of articles about teaching psychomotor skills, Guenzel et al. included an example of an assessment rubric for a preclinical restorative procedure. Each step in an amalgam cavity preparation was carefully identified in this rubric. Tests for students to use in completing each step and specific descriptors for each of three attributes applicable to each step were clearly laid out in a matrix format. Nimmo and Knight described revision in a fixed prosthodontic curriculum to emphasize patient-driven, competency-based, and criterion-referenced evaluation including self- and peer assessment. To facilitate attainment of discrimination skills, the same evaluation forms were used in preclinical, junior, and senior year competency examinations. The authors provided two examples of evaluation rubrics, where procedural steps and tests for each step were sequentially identified. Criteria in each matrix specifically described measures of honors, clinically acceptable, and standard not met for each step in production. The

students were required to evaluate their performance prior to reaching agreement with a peer evaluator. Finally, the faculty member evaluated the product. These researchers concluded that the new curriculum was consistent with current dental practice and national licensing examinations. Pass rates for the students in that curriculum on regional licensure examinations (CORE/NERB) also improved in comparison to regional averages. In another study, Brown et al. designed a scoring rubric for pharmacy students (N=104) to assess aseptic technique using three descriptors (acceptable, needs improvement, likely harmful). Application of this rubric allowed quantification of a previously unmeasured skill—sterile product preparation. Student improvement in technique was successfully documented, and the percentage of students receiving one or more ratings of “likely harmful” decreased significantly (p<0.001). Additionally, these pharmacy students in their first year of practicing aseptic technique received specific feedback that assisted in their learning. The researchers also identified curricular deficiencies through application of the rubric. This rubric provided a quantitative assessment instrument that detailed the proper order of production with clear criteria that served in aiding the novice student’s successful performance of a new skill.

Rating scales or checklists differ from rubrics. These types of evaluation instruments itemize evaluation criteria but do not specifically describe each criterion as rubrics do. Rather, a simple numerical or descriptive scale for each criterion is identified, such as poor, acceptable, good, and excellent. Checklists can be used to delineate sequencing of specific steps in a process. Rating scales also may be used for global assessment of students’ overall clinical progress. Development and implementation of the SCIRS (Simulated Client Interview Rating Scale), a rating scale with thirty-nine items and three scale points (not done, done, and done well), was described by Arthur. The SCIRS was designed to both provide guidelines for student learning and to provide summative assessment of nursing students’ communication skills prior to clinical placements. Students were videotaped interviewing simulated clients and subsequently rated their own interview. The researcher viewed and scored each student’s video. Overall student scores were found to correlate significantly (p<0.001) with the researcher’s scores. Application of standardized rating forms detailing steps required for production may enhance student learning, self-assessment, and faculty calibration.
Traditional Versus “Nongraded” Assessment

Traditional evaluation systems use frequent numeric assessments of student performance in preclinical and clinical settings. Several studies of evaluation of patient care in the clinical setting have found student satisfaction and clinical production to be enhanced by using “nongraded” assessments. These nontraditional models of evaluation include normative assessments, pass-fail systems, or grading only key portions of students’ clinical production and providing feedback and nongraded assessment for the majority of the clinical experience. When designing preclinical evaluations with consideration of the motor skills theory, one needs to realize that the novice student’s learning of motor skills is affected by external factors such as stress or fatigue. New experiences such as dental or dental hygiene instrumentation may be difficult to learn, and stress can compound the problem. Studies in the literature describe assessment systems that have been successful in clinical applications in reducing students’...
Development and use of nongraded clinical experiences at Baylor College of Dentistry (BCD) was described by Taleghani et al. Ninety-nine percent of the fourth-year dental students completed a satisfaction survey asking them to compare the new normative assessment system used in the fourth year to the traditional numerical grading system that was in effect their third year. The normative system compared student performance to evidence-based clinical standards and replaced the previous traditional summative (numerical) grading system. The majority of students (77.6 percent) believed their interactions with the clinical faculty were improved with the new system, and many (71.9 percent) found the clinical environment to be less stressful. A similar survey of clinical faculty (n=19) indicated the majority (89.5 percent) believed that their evaluation of student performance was more accurate under the normative system of clinical evaluation. In a subsequent article, the same authors described how graded and nongraded assessments were merged into grade point averages at BCD. The authors believed this new system more accurately distinguished the students’ clinical performance. Similar research conducted by Dodge et al. found that an experimental group of senior dental students (n=10) who functioned without overt procedural requirements and with less emphasis on daily grades both outproduced and experienced less stress when compared to requirement-driven students (n=72). The nonrequirement group had significantly higher grade point averages (GPAs) on comprehensive clinical exams (p=0.017), overall general practice GPAs (p<0.001), and completed comparative numbers of procedures. No students in the nonrequirement group failed the state board exam, whereas 17 percent (n=12) failed in the traditional curriculum group. The pilot group also reported significantly less stress regarding what they needed to accomplish to graduate (p<0.001).

McCann et al. compared dental hygiene students in their first semester of patient care randomly assigned in two grading systems (letter and pass/fail). Findings of similar levels of performance (defined by the researchers as the number of errors in scaling and polishing) within the two systems led the researchers to propose that a pass-fail system be incorporated into this program. A posttest questionnaire revealed that the students (n=9) in the pass/fail system were more motivated in completing clinical tasks than the letter-graded students (n=10). Both groups evidenced high levels of performance. Students in the pass-fail groups viewed both types of grading as less significant and less motivating to clinical performance than the students receiving letter grades (p<0.05). Chambers described an evaluation system used at the University of the Pacific (UOP), where each quarter clinical instructors used a Clinical Competency Rating Form to evaluate understanding as well as clinical performance of procedures for dental students in all clinical courses. These faculty ratings were used as a part of a competency-based clinical grading system. Consistency among raters was high (alpha >0.747) in several skill areas. This rating form was derived through consideration of UOP’s competency statements and allowed evaluation of the students’ understanding as well as clinical performance of procedures. This quarterly rating system replaced daily grading and was adopted by all departments for use on clinical competency exams.

Discussion

Successful instruction of novice preclinical learners requires understanding motor skills theory, motor performance, and implicit learning, as well as the schema of stages of learning. For novice students, explicit directions given in small steps and provision of timely and appropriate feedback on performance are techniques that facilitate learning of motor skills. Repetition and continued practice improve performance. Recognition skills in which the student learns to visualize an appropriate end result should be formally taught and emphasized prior to any skill performance. Teaching novice students how to accurately self-assess may improve performance or, at a minimum, associate performance with self-assessment capabilities. Designing and applying appropriate evaluation instruments may contribute to effective teaching, calibration of faculty, and student learning. Rubrics and rating scales designed with specific criteria related to each step in a preclinical skill performance can be valuable tools for both the learner and the evaluator. Novice students benefit from criteria that are explicit and meaningful. Further study is needed to assess the impact of nontraditional grading systems for preclinical and clinical courses.
Pass/fail, normative, and less frequent grades in the preclinical environment coupled with frequent “non-threatening” feedback may reduce students’ stress while preserving and enhancing performance.

REFERENCES