

Integrated Testlets in Optics and Photonics: A Novel Assessment Tool and its Online Deployment

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Abstract: We describe opportunities for integrated testlets as assessments in optics and photonics courses. This new scaffolded multiple-choice approach adopts an answer-until-correct framework that can test complex understanding through either offline or online delivery. © 2021 The Author(s)

1. Introduction

We have recently developed a new student assessment tool, called an *integrated* testlet [1,2], which has been successfully delivered to thousands of students at several educational institutions across Canada, both through paper-based and online means. An integrated testlet assesses students' understanding of complex knowledge through a set of scaffolded multiple-choice questions, each adopting an answer-until-correct format. Compared to typical multiple-choice-based tests that ask questions (called *items*) that are wholly independent of each other, an integrated testlet purposefully uses an answer-until-correct format to allow items to then become interdependent so they can build on one another. This scaffolding allows for the assessment and learning of deeper and more interconnected aspects of a course. Testing such interconnectivity of knowledge is particularly useful within STEM disciplines, but is especially beneficial in cumulative and strongly-interdisciplinary fields in physical science such as optics and photonics.

Since their inception, originally targeted to university students during tests and examinations using paper-based question sheets and scratchable immediate-feedback answer cards, the potential scope of integrated testlets has broadened enormously. Additional students who can benefit from this tool include those enrolled in technical courses, those studying remotely, and also those in grades 9-12. The method of delivery has broadened to include textbook delivery to aid with student self-study, and online delivery with its benefits of automatic scoring, self-pacing, and rapid access to test psychometrics. The educational goals have been augmented to include formative learning during testlet deployment, and enhanced student engagement with increased focus and concentration, together with group discussion, learning, and assessment. Integrated testlets have been delivered before class, in class, and at summative points throughout the semester. They facilitate a more conversational and dialogue-based aspect to education and to training [3], and, lastly, by forcing deliberate and mindful composition practices among instructors, integrated testlets enhance their pedagogical skills and acumen.

Within this ETOP presentation we shall expand on the points listed below. In particular we shall convey and substantiate the educational and training benefits from adopting integrated testlets, with concrete examples taken from optics and photonics at both introductory and upper-year undergraduate levels. We will share good practices that can aid instructors and trainers when composing integrated testlets, and when deploying them within various settings. Specific examples from optics and photonics will be provided, with a description of how these have been, or are being, deployed through paper-based, textbook-based, and online delivery.

2. Integrated testlets; the why

Some key advantages of integrated testlets include their ability to:

- assess student knowledge and understanding through a course-focused narrative that increases student engagement with the topic at hand beyond that which we observe with the more traditional 'firehose-type' approach of asking many unrelated, surface-deep and less purposeful questions.
- provide to students, when and as needed, the correct answer for each step in a question after the student has attempted this step several times, which circumvents problems associated with double jeopardy as students advance through the cumulative aspects of a question.
- reduce errors and misinformation from being retained by students associated with them incorrectly selecting or guessing an erroneous answer before advancing through a question.

- reaffirm for students what they do and don't understand, which helps students reconcile with their current knowledge and in turn helps them advance from a position that is grounded in the reality of their current understanding.
- allow the instructor to assess more challenging concepts and procedures in a cohesive, low-stakes manner, as compared with traditional question formats.

These advantages apply to integrated testlets in general, whether their delivery be paper-based, textbook-based, or through online means. Additional advantages to textbook deployment, as is currently being prepared by one of us (RS), for the new 4th-edition of the classic Pedrotti text [4], include that:

- seemingly-disparate topics from a single chapter may be readily merged using a single narrative with real-life examples, which students explore at their own pace, with assistance provided at each step if needed.
- the integrated testlet can function as a springboard for a particular concept in class, by unpicking its narrative with which students are already familiar, to address conceptual hurdles that feature in many topics in optics and photonics.
- different versions of these integrated testlets can be readily deployed, perhaps as pre-class tasks, and perhaps in groups, to rapidly ground students to the subject at hand, irrespective of what course or activity they were doing before class.

Additionally, when courses recently moved to remote delivery, we demonstrated that online deployment of integrated testlets provides the following extra benefits for students and for instructors:

- marking is now instantaneous, which circumvents summing scratches on scratch cards, and obviates the need for purchase of the same.
- individualized and highly-randomized questions can be asked of students such that the combination of a question's input variables, distractors, and option ordering together constitute a unique question for every student which helps arrive at 'cheat-resistant' online questions.
- the instructor can record how long, and in which order, each item within a question set is answered, permitting question optimization and rapid psychometric analysis.

3. Integrated testlets; the how

We have over the past few years accrued extensive experience from constructing more than 100 different integrated testlets, in topics from classical mechanics and biophysics to optics and photonics. In this presentation we shall focus on a particular integrated testlet, taken from an upper-year modern optics course, to convey key aspects of integrated testlet construction, optimization and deployment. This particular example assesses student understanding of *coherence*, and in particular of the concepts of *transverse coherence length*, *spatial coherence width*, and of *volume of coherence*.

[1] A. D. Slepkov, "Integrated Testlets and the Immediate Feedback Assessment Technique," *Am. Journ. Phys.*, **81**, 782-791 (2013).

[2] A. D. Slepkov and R. C. Shiell, "Comparison of integrated testlet and constructed-response question formats," *Phys. Rev. ST Physics Ed. Research*, **10**, 020120, 1-15 (2014).

[3] R. C. Shiell and A. D. Slepkov, "Integrated testlets: A new form of expert-student collaborative testing" *CELT*, **VIII**, 201-210 (2015).

[4] Pedrotti, F., Pedrotti, L., and Pedrotti, L., *Introduction to Optics*, Cambridge University Press (2017).