

## **Making Learning Whole: Toward the Development of an Instrument Operationalizing Perkins' Model**

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### **Abstract**

The push for stronger links between engineering education research and practice requires that taking a more scholarly approach to teaching became the norm instead of the exception across all engineering education. This paper seeks to make the case that there is a lack of tools available for achieving some of the goals of the field, such as the one aforementioned, and presents findings from a set of research activities designed to help address this need. More specifically, this *work in progress* paper describes the early stages of a study that uses *Making Learning Whole* instructional design framework and Messick's instrument development theory to develop a validated rubric that can be used to design and evaluate the effectiveness of engineering education courses in formal and informal contexts. This paper describes the early stages of an engineering education research endeavor that will be an important contribution to the field. It is situated in an appropriate theoretical and methodological framework. This paper affirms that *Making Learning Whole* is an instructional framework that is relevant and applicable to engineering education; holds tremendous promise for designing and evaluating a variety of engineering education experiences; and can be operationalized into a pedagogical resource that can help bridge the gap between research and practice in engineering education.

### **Overview and Objective**

There have been numerous initiatives to advance the state of the art of practicing engineering education. Though progress seems slow at time, there have been major shifts in engineering education over the past century-- two of which include a shift toward an emphasis on outcomes-based assessments and more student-centered learning<sup>1</sup>. Streveler, Smith, and Pilotte<sup>2</sup> argue that aligning content, assessment and pedagogy (CAP) are essential to outcomes-based assessment, and that an important part of this alignment includes anchoring education practice in the appropriate educational theory (i.e., learning theory, assessment theory, and instructional theory). While we may agree that there needs to be an alignment of CAP, there is a need for more guidance on how to enact this ideal in the development and/or evaluation of courses as we strive to design aligned courses and determine whether existing courses are aligned. Perkins' *Making Learning Whole* instructional design framework<sup>3</sup> is among the three models Streveler, et al.<sup>2</sup> recommends engineering educators use to design courses with aligned content, assessment, and pedagogy. This paper is the beginning of a larger study that builds on this work. The authors of this study agree that Perkins' framework is relevant and applicable for designing learning experiences in engineering education, and argue that the utility of the framework can be extended to evaluate the effectiveness of course designs as well.

The objective of the larger study associated with this paper is to develop a valid rubric that operationalizes the *Making Learning Whole* framework<sup>3</sup>, such that it can be used to guide the design of courses and to evaluate the extent to which an engineering course includes an aligned content, assessment and pedagogy. This study uses a traditional instrument development

approach to developing this rubric-- namely, an adaptation of Messick's unified theory for instrument development and validation<sup>4</sup>. The scope of this *work in progress* paper focuses on the foundation for the first step in this process, which includes determining the theoretical rationale for the rubric.

## Motivation

Innovating the state of the art in engineering education requires a “closed loop” between research and practice. Recently, Jamieson and Lohmann<sup>5</sup> articulated the interrelationships between *what* needs to be changed in engineering education, *how* to drive change in this context, and *who* should drive change. Furthermore, they proposed a model of systematic engineering education innovation that is based on a continual cycle of research and practice, which, if adopted, would “both continually advance the body of knowledge on engineering learning and result in the implementation of more effective and replicable educational innovations, with the end result being better-educated students” (p. 1); see Figure 1. Assessment is a necessary part of the cycle. It clarifies learning intentions, suggests development of activities to measure learning, provides feedback to students, and helps students become independent learners. Assessment referred to in this paper is not the kind to give grades but rather as a part of instruction to improve and facilitate learning. A rubric is a tool that provides clear expectations and criteria for assessment of student learning<sup>6</sup>. A rubric includes the aspects of a performance to be assessed as well as a description of the criteria used to assess each aspect<sup>6</sup>. The motivation for developing a *Making Learning Whole*<sup>3</sup> rubric is consistent with other initiatives to advance the state of the art practice in engineering education.

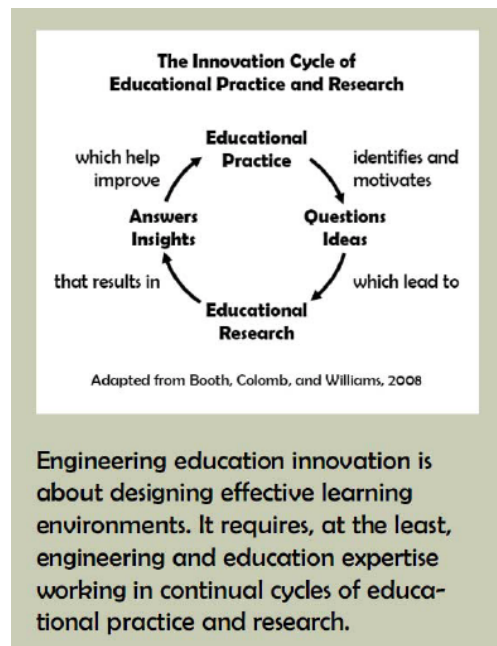


Figure 1. Innovation Cycle of Educational Practice and Research<sup>5</sup> (p. 6)

The Scholarship of Teaching and Learning is an area of scholarly work that is receiving increased attention in higher education and many engineering education faculty are embracing more scholarly approaches to teaching and learning. Streveler, et al.<sup>2</sup> outlined a wide range of inquiry in engineering education, and was informed by scholars in and outside the field of engineering education (e.g., Hutchings and Sulman, 1999; Lohmann, (n.d.); and Streveler, Borrego, Smith, 2007 as cited by Streveler, et al.<sup>2</sup>). Table 1 summarizes the variety of ways in which engineering faculty can engage in engineering education research and practice in four levels of inquiry.

Level 0	<b>Teach:</b> Teach as taught and without reflection
Level 1	<b>Effective Teaching:</b> Teach using accepted pedagogical practices
Level 2	<b>Scholarly Teaching:</b> Teach; Assess teaching; make improvements
Level 3	<b>Scholarship of Teaching and Learning:</b> Engage in educational experimentation; share results
Level 4	<b>Engineering Education Research:</b> Conduct educational research; publish in scholarly journals

Table 1. Levels of Inquiry in Engineering Education<sup>2</sup>

We agree with other engineering education researchers who have said engineering faculty should work at a Level 2 or higher<sup>2</sup>. While this might be an ideal we should strive for as a community of engineering educators, many members of this community may struggle with how to effectively contribute to this goal. Literature and rubrics exist that help college instructors assess and redesign courses using learning-centered principles to help them perform at a Level 2 or higher<sup>7, 8</sup>. For example, Blumberg<sup>8</sup> provides several learner-centered rubrics focused on the instructor role and content functions in teaching as well as examples that assist educators in assessing student learning. These and similar instructional guides and rubrics provide some direction for improving scholarly teaching. Yet, one underlying purpose of this study is to assist engineering educators in improving the extent to which they can take a scholarly approach in their pedagogical practices, and advance in the levels of inquiry in engineering education. This will be accomplished by developing a rubric based on the *Making Learning Whole*<sup>3</sup> instructional design framework that will be useful for designing courses and assessing course designs. This work in progress paper is the beginning of this endeavor. The remainder of this paper describes the *Making Learning Whole*<sup>3</sup> framework, and existing literature related to it. It also provides an overview of the theoretical lens guiding this study and present preliminary insights related to the first of six steps in the development of the rubric.

### ***Making Learning Whole* Instructional Design Framework**

Instructional frameworks are mechanisms for operationalizing learning theories, and provide guidance on how to design learning experiences in ways that are consistent with the instructor's perspective on how people learn. *Making Learning Whole*<sup>3</sup> is an example of an instructional framework that integrates many of the latest findings on how people learn, and proposes seven principles on how to design an individual or set of learning experiences in ways that facilitate comprehensive learning in a variety of course designs.

Perkins describes his approach as *learning by wholes* and uses a sports metaphor to expound on the following seven principles: 1) Play the Whole Game; 2) Make the Game Worth Playing; 3) Work on the Hard Parts; 4) Play Out of Town; 5) Uncover the Hidden Game; 6) Learn From the Team; and 7) Learn the Game of Learning. Each of these will be described in layman's terms.

"Play the Whole Game" speaks to the need to design learning experiences that enable students --right from the beginning-- to understand a concept not as an individual, isolated element, but as a whole. This should include exposure to the *whys* and *hows* of the concept and where the concept fits in a larger context. "Make the Game Worth Playing" involves capturing students' attention by motivating them to engage in interesting learning experiences, understand the usefulness and relevance of the concept being taught, and providing opportunities to for autonomy and choice. "Work on the Hard Parts" is a principle that calls for acknowledging and anticipating the moments in the learning experience(s) that students will find most challenging, and integrating learning activities (informed by theories of difficulty) that target these areas and help ensure that students get past the difficulties. "Play Out of Town" is focused on the transfer of knowledge and skills to new context. Said differently, the focus of this principle is to facilitate transfer of learning by creating activities that make students connect the new concept with their prior knowledge and understand how the new concept can potentially connect to other knowledge and situations, or experiences they might face in the future. "Uncover the Hidden Game" is focused on revealing the tacit knowledge that underlies many of the things that experts (with respect to a concept) tend to do when faced with the situation. The focus is on emphasizing the mental processes that underlie learning a particular concept or executing a particular task. "Learn from the Team" involves constructing a learning environment that promotes interactions among learners, and the attainment of learning that is more meaningful than what could be attained by learning alone. The last of the seven *Making Learning Whole*<sup>3</sup> principles is "Learn the Game of Learning". With this principle, the goal is to encourage learners to become self-directed, and develop skills that are necessary for monitoring and directing their own learning (i.e., practice good metacognition).

### ***Making Learning Whole in the Literature***

While Perkins' model<sup>3</sup> is consistently cited in research literature as an effective framework to use when designing learning experiences<sup>9,10</sup>, existing studies do not provide explicit examples of applications of Perkins' model to design or evaluate a range of learning experiences in formal or informal learning environments. Research studies reference Perkins' model as an ideal framework that supports designing learning experiences and reflect the

model's principles in recommending learning approaches that embrace holistic learning techniques. Engineering education researchers Streveler, et al.<sup>2</sup> uphold Perkins' model<sup>3</sup> as an exemplar model for designing and assessing learning experiences with aligned content, assessment, and pedagogy. While leading engineering education researchers uphold Perkins model as an exemplar, there are few examples of it being used among engineering educators; the majority of instances where Perkins is used in non-engineering contexts.

For example, Liljeström et. al<sup>11</sup> state that learning should be a holistic process that includes incorporating evaluative aspects into students' experiences. In a design experiment study, sixth grade students in Finland, tasked with teaching third grade students about the Ice Age, developed knowledge using activity theory in a type of "flipped" classroom setting centered on informal learning, the use of technology, and projects. In this study, Perkins' framework<sup>3</sup> is referenced in correspondence to the idea that in designing instructional approaches that make learning whole, educators can create learning environments that encompass open-ended tasks, diverse and heterogeneous learning community, and the use of mediated tools<sup>11</sup>. Researchers also cite Perkins' ideas to support arguments for designing learning experiences that integrate content and construction of knowledge in an experience in order for it to be most beneficial for learners. In a final report of a three-year study of the New Zealand Curriculum and curriculum implementation practices in primary and secondary schools, Hipkins<sup>12</sup> assessed that students may learn content knowledge in "pieces", which Perkins describes as "elementitis"(p.4). Subsequently, there is a lack of knowledge that "sticks" with students to allow them to construct relevance and meaning from knowledge resulting in a lack of achievement.

Some researchers develop principles that reflect the ideals of Perkins' model, and use these principles to design learning experiences. For example, to assess ninth-grade readers' comprehension of reading tasks, STEM education researchers<sup>13</sup> created comprehension tasks, selected challenging texts, and implemented a six-step comprehension lesson framework that reflects principles similar to Perkins' model. Although Perkins' model is not directly referenced or used in the article, the authors provide a framework that is similar to Perkins' model in that it explains how to design good learning experiences using specific steps related to the process of learning. Apart from this example, Perkins' model is recognized as a seminal framework for understanding how to design learning experiences. Yet while this framework is becoming more widely used among engineering educators, few studies reveal how engineering educators have used it to inform the development of engineering courses in a spectrum of course designs and/or to evaluate course designs.

Generally, research studies lack explicit examples or applications of Perkins' model to design and/or evaluate the design of specific learning experiences. In light of this gap, it would be beneficial to create an instrument that can guide researchers and educators in designing and assessing learning experiences using the model. Such an instrument could support researchers and educators in their execution of curriculum development, pedagogy, and assessment in a seamless and efficient manner. Moreover, they could use the instrument to assist with scaffolding during the design of new courses or as a tool for reflections on the effectiveness of

existing courses. The larger study surrounding this paper is designed to address the need for such an instrument. This rest of this paper presents the methodological framework guiding this study, along with insights that serve as the foundation for developing the contents of an instrument (in the form of a rubric) that operationalizes the *Making Learning Whole* framework<sup>3</sup>. While engineering education researchers and practitioners are the users and stakeholders associated with instrument design, the hope is that the rubric that results from this study will be useful for designing and evaluating effective learning experience in and beyond engineering education.

### **Messick's Model for Instrument Development**

The methodological approach to the overall study is an adaption of Messick's unified theory for instrument development and validation<sup>4</sup>. Messick defined validity as "an overall evaluative judgment of the degree to which empirical evidence and theoretical rationales support the adequacy and appropriateness of interpretations and actions based on test scores or other modes of assessment" (p.245)<sup>14</sup>. Based on Messick's theory, validity includes six different facets: content, substantive, structural, generalizability, external, and consequential.

These six aspects can be briefly defined as:

- A. Substantive Aspect: develop a theoretical basis for observed consistencies in responses
- B. Content Aspect: includes evidence of content relevance and representativeness of the construct domain
- C. Generalizability Aspect: evaluates the extent to which the scores and interpretations generalize to other groups, settings, and tasks
- D. Consequential Aspect: evaluates the implications of the use of the instrument and score interpretations as a foundation for taking actions (especially as it relates to issues of bias and fairness); and includes evidence for evaluating both the intended and unintended consequences of use and interpretation
- E. Structural Aspect: evaluates the fidelity of the scoring structure to the structure of the construct domain of interest
- F. External Aspect: includes multi-method comparisons of convergent and divergent evidence like comparisons with similar impact frameworks

Messick's model is widely used by psychometricians and has been translated by engineering education researchers<sup>15</sup> into an instrument blueprint researchers can use to guide the development of items and the collection of validity evidence; their translation is pictured in Figure 2.

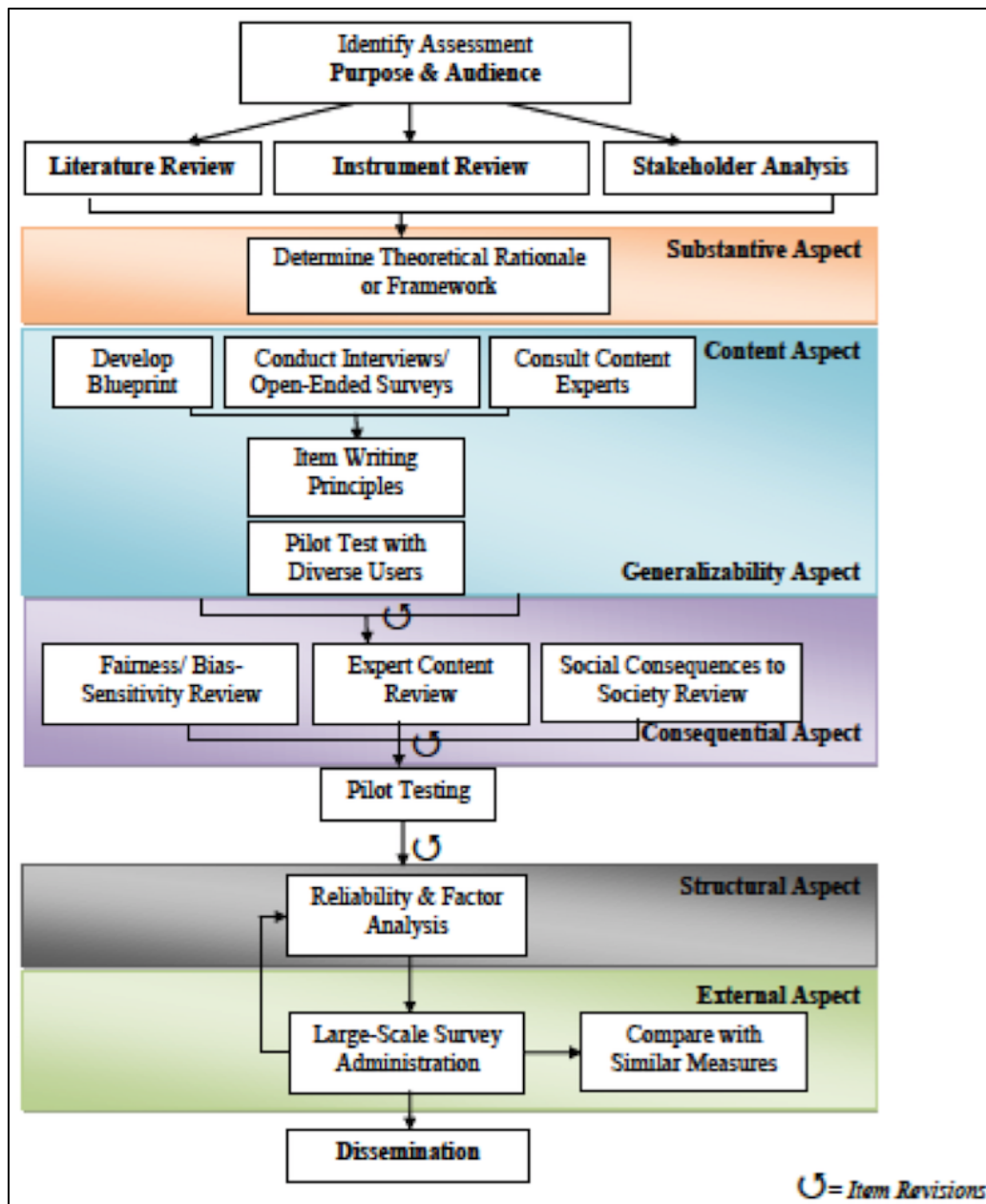


Figure 2. Blueprint of Messick's Theory unified theory for instrument development and validation<sup>4</sup> according to engineering education researchers<sup>15</sup>

While traditionally, the instrument development process includes a series of statistical analysis as part of developing a psychometrically sound instrument, and Messick's framework is one approach to instrument development, but Purzer and Cardella's blueprint reveals that the framework is much broader than a series of statistical analyses. It brings in activities like a literature review, review of existing instruments, stakeholder analysis, and content experts perspectives. The rubric that will result from this study employs this blueprint and will rely on multiple sources: 1) literature on *Making Learning Whole*<sup>3</sup>; 2) literature on how to evaluate learning associated with the *Making Learning Whole* principles; 3) literature on effective course



design; 4) opinions of content experts; and 5) perspectives of engineering education researchers and practitioners. The rest of this paper highlights steps that have been made toward developing the substantive aspect of the validity of the developing rubric.

### **Establishing Substantive Validity-- A Work in Progress**

Establishing substantive validity of an instrument includes many tasks. It includes reviewing the literature and other instruments related to the purpose and audience associated with the instrument being developed. It also includes conducting a stakeholder analysis to determine the key players connected to the instrument being developed. Collectively, these tasks lead to determining the framework for the instrument. The purpose and intended audience for the instrument are described in the previous sections of this paper. At this stage of this work in progress, the focus is on the existing literature and instruments. Again, this is the focus of this paper. The hope is that the initial insights will provide enough information to have a meaningful conversation among colleagues about other instruments related to the constructs associated with the seven principles of the *Making Learning Whole* framework.

Within each the seven principles of the Making Learning Whole framework are embedded constructs around which whole bodies of literature exist. The second principle, “Make the Game Worth Playing”, illustrates this point well. Again, the focus of this principle is motivating the learner, and creating an environment in which learners are motivated to engage in the learning experience. It goes without say, but the topic of motivation is well established in scholarly literature; experts in various fields (e.g., education, business) have studied this topic for decades. (See section “*Making Learning Whole* Instructional Design Framework” for an overview of each principle.) Because each of the seven principles has this characteristic –to some extent— we hypothesize that this may be part of the reason why there is no established instrument around the *Making Learning Whole* framework. Such an effort requires synthesizing the instruments from at least seven other bodies of work; and there are some instances where more than one construct is embedded in the principle (e.g., principle seven – learn the game of learning—includes both self-directed learning and metacognition). Because of this complexity, we imagine that reviewing the literature associated with each of the seven principles will require a “divide and conquer” strategy.

What will be presented next is the beginning of attempt to identify instruments that reflect the concepts associated with each of the seven principles in Perkins’ framework. Two authors were assigned a subset of principles to focus on during this initial review of the literature; see Table 2.

<i>Making Learning Whole</i> <sup>3</sup> Principles	Author Assigned			
	A	B	C	D
1. Play the whole game	*		*	
2. Make the game worth playing	*		*	
3. Work on the hard parts	*			*
4. Play out of town		*		*

5. Uncover the hidden game		*	*	
6. Learn from the team		*	*	
7. Learn the game of learning		*		*

Table 2. Assignments for Reviewing Existing Instruments

After separately reviewing description of the principles and becoming more familiar with the nuances of each one, the research team met to discuss the underlying ideas/constructs associated with the construct. We collectively brainstormed and came to a consensus on the major underlying ideas/constructs associated with each of the principles. This discussion was the basis for the contents in the “*Making Learning Whole* Instructional Design Framework” section. With this shared understanding, each member of the research team began reviewing the literature around the topic to find existing instruments. What will be presented next is a preliminary review of existing instruments related to each of the seven principles in the *Making Learning Whole* framework.

### Preliminary Review of Existing Instruments

In this section, we highlight some existing survey instruments that assess teaching experiences in alignment with elements of Perkins’ model. In the table below, we not only provide an overview of the purpose of the assessment, but offer examples items in instruments. Such insights will be useful in next phase of the instrument development process. We provide insights about existing tools as well as details about how our instrument addresses a gap in designing and assessing learning experiences, which is lacking from these tools. Specifically, existing instruments focus on assessing student learning experiences rather than assisting educators with being able to design and assess whether they have achieved creating holistic learning experiences for their students<sup>16-21</sup>. Existing survey instruments may assess concepts related to Perkins’ principles as well as correlating constructs. For example, for the principle “learn the game of learning”, instruments may assess how students learn how to learn as related to the concepts of learning risk awareness, self-efficacy, and other constructs<sup>21</sup>. Thus, existing survey instruments focus on some of the aspects related to each of Perkins’ principles; yet there are many layers that exist in examining each principle. This adds breadth examining the application of these principles, but does not provide clarity regarding how to design or assess learning experiences for these aspects.

Table 3. Highlights of Existing Instruments

Perkins’ Principle (Brief Summary of the Principle)	Example of Related Instrument	Example Items from the Instrument
<b>1. Play the whole</b>	<i>Development of an</i>	● <i>The teacher directed us with some</i>

<p><b>game.</b> (Engage Learners in a Junior Version)</p>	<p><i>Instrument for assessing undergraduate science students' perceptions: the problem-based learning environment inventory.</i><sup>20</sup></p>	<p><i>metacognitive questions.</i></p> <ul style="list-style-type: none"> <li>● <i>The problems we studied were about everyday life.</i></li> </ul>
<p><b>2. Make the game worth playing.</b> (Motivate Learners)</p>	<p><i>Enhancing student motivation and engagement: The effects of a multidimensional intervention</i><sup>22</sup></p>	<ul style="list-style-type: none"> <li>● <i>Program module: Valuing</i> <ol style="list-style-type: none"> <li>1. <i>Prepare—Define factor, general rules, advance organizer for Module</i></li> <li>2. <i>Generate—</i> <ol style="list-style-type: none"> <li>a. <i>Linking school to the world</i></li> <li>b. <i>Linking school to one's life</i></li> <li>c. <i>Skills learned in school</i></li> </ol> </li> <li>3. <i>Reflect—Identifying important messages, how to apply them, and rating one's confidence in applying messages.</i></li> <li>4. <i>Closure—Revisiting important strategies and having work signed off by oneself and one's parent/teacher</i></li> </ol> </li> </ul>
<p><b>3. Work on the hard parts.</b> (Isolate and Improve Learners' Abilities in Difficult Areas)</p>	<p><i>Development of an instrument to measure perceived cognitive, affective, and psychomotor learning in traditional and virtual classroom higher education settings.</i><sup>19</sup></p>	<ul style="list-style-type: none"> <li>● <i>I can organize course material into a logical structure.</i></li> <li>● <i>I can demonstrate to others the physical skills learned in this course</i></li> </ul>
<p><b>4. Play out of town.</b> (Transfer Learning to Unfamiliar Contexts)</p>	<p><i>Development of a Generalized Learning Transfer System Inventory.</i><sup>18</sup></p>	<ul style="list-style-type: none"> <li>● <i>I get excited when I think about trying to use my new learning on my job.</i></li> <li>● <i>I am confident in my ability to use newly learned skills on the job.</i></li> </ul>
<p><b>5. Uncover the hidden game.</b> (Reveal Tacit knowledge)</p>	<p><i>Knowledge management capability assessment: Validating a knowledge assets measurement instrument.</i><sup>17</sup></p>	<p><i>Abbreviated KMCA scale items:</i></p> <ul style="list-style-type: none"> <li>· <i>Search capabilities</i></li> <li>· <i>Information about internal &amp; external experts</i></li> <li>· <i>Accessibility of repository(ies)</i></li> </ul>

		<i>Ease of finding documents</i>
<b>6. Learn from the team.</b> (Facilitate Engagement and Interactions Among Learner)	<i>Measuring cognitive and psychological engagement: Validation of the Student Engagement Instrument.</i> <sup>16</sup>	<ul style="list-style-type: none"> <li>• <i>When I do schoolwork I check to see whether I understand what I'm doing.</i></li> <li>• <i>Students at my school are there for me when I need them.</i></li> </ul>
<b>7. Learn the game of learning.</b> (Promote Learners' Metacognition, and Self-regulation)	Development of an Instrument Designed to Investigate Elements of Science Students' Metacognition, Self-Efficacy and Learning Processes: The SEMLI-S <sup>21</sup>	<ul style="list-style-type: none"> <li>• <i>I seek to connect what I learn from what happens in the science classroom with out-of-school science activities.</i></li> <li>• <i>I evaluate my learning processes with the aim of improving them.</i></li> </ul>

A brief survey of existing instruments indicate that existing instruments assess and evaluate student learning experiences, but lack instruction about how to design and assess these experiences, see Table 3. In contrast to existing instruments which focus on assessing principles associated with Perkins' model, our instrument will address a gap in instruments that are available by developing a rubric-like instrument to assist designers of learning experiences in: 1) how to develop learning experiences aligned with Perkins' model and 2) how to assess whether a designed learning experience aligns with Perkins' model principles. Using Perkins' model as a guideline, we will create this instrument by identifying, modifying, and designing scale items that reflect Perkins' principles and that educators can use to design and assess learning experiences. We will then pilot these elements with educators who are designing learning experiences and then reverse engineer our tool to help these designers assess whether they are effectively designing a learning experience aligned with Perkins' model.

### **Discussion and Future Work**

In this paper, we presented the first stage of a larger project whose aim is to develop a tool that will help educators develop courses and learning experiences as well as assess the effectiveness of their design and their pedagogical objectives, offering both planning and feedback functions. More specifically, this paper situates this study in the context of broader engineering education priorities, provides an overview of the *Making Learning Whole*<sup>3</sup> framework and Messick's theory<sup>4</sup>, and highlights some of the existing instruments related to the seven *Making Learning Whole* constructs<sup>3</sup>.

In our attempt to catalog the development and validation strategies of instruments currently being used to measure various constructs within the *Making Learning Whole*<sup>3</sup> framework, we surveyed the literature. We found literature that supports assessing student

learning in various forms, yet this research did not provide explicit examples of instruments that supported how to design student learning experiences or implement pedagogical strategies. As a result, this paper hopes to make the case there are a lack of tool that provide guidance on how to design and develop aligned course, and by extension, operate at a level 2 engineering educator or above.

We learned from the research and the tools we found that our future instrument will have to be flexible, expandable, and robust. We learned that as the tool is developed, we will need to build a structure that helps educators be specific in their objectives so that the assessment measures not what students learned but the environment and pedagogical activities that were the pathway to student learning. We intend for tool to be applicable across the lifetime of engineering learning, from early childhood to postsecondary education, and appropriate for formal and informal educational settings. Our next step is continue our research into the pre-service teacher space to identify methods by which educators evaluate curriculum development and pedagogical strategies of teacher candidates, and investigate how teacher board certification portfolios are evaluated. This will allow us to integrate best practices from teacher education and professional development into the Perkins' framework<sup>3</sup>. Our first instrument will progress through multiple validation sequences and setting pilots. We believe this kind of work will advance the Scholarship of Teaching and Learning and will serve as a tool by which engineering educators can develop and reflect on their teaching, impacting the next generation of engineers through positive learning experiences.

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