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BOARD #152: WIP: Teaching practices assessment tools as the foundation for identifying entrepreneurial education best practices

Mr. Marcus Melo de Lyra, The Ohio State University

Marcus is a second-year Ph.D. Candidate in the Engineering Education Department (EED) at The Ohio State University. His research interests include teaching faculty development and early-career faculty experiences. Before joining the EED program, Marcus studied two years in the Engineering Education Systems and Design program at Arizona State University, he also earned his BS in Civil Engineering at the Federal University of Rio Grande do Norte and his MS in Civil and Environmental Engineering at the Federal University of Campina Grande in Brazil.

Sherri Youssef, The Ohio State University

Sherri Youssef is a PhD candidate in the Department of Engineering Education at The Ohio State University. Her research interests include understanding the motivation of regional campus undergraduate engineering students to persist and how the need to belong inform one's persistence in engineering. She completed both her M.S. in Mechanical Engineering and her B.S. in Materials Science and Engineering at The Ohio State University as well.

Peyton OReilly, The Ohio State University

Peyton O'Reilly is pursuing her B.S. in Biomedical Engineering at The Ohio State University. She is involved in the Department of Engineering Education as an Undergraduate Research Associate. Her research interests include sense of belonging in engineering and curriculum development in the first year programs.

Shukufe Rahman, The Ohio State University
Dr. Benjamin Ahn, The Ohio State University

Dr. Benjamin Ahn is an Associate Professor at The Ohio State University in the Department of Engineering Education.

Dr. Adam R Carberry, The Ohio State University

Dr. Adam R. Carberry is Professor and Chair in the Department of Engineering Education at The Ohio State University (OSU). He earned a B.S. in Materials Science Engineering from Alfred University, and received his M.S. and Ph.D., both from Tufts University, in Chemistry and Engineering Education respectively. He recently joined OSU after having served as an Associate Professor in The Polytechnic School within Arizona State University's Fulton Schools of Engineering (FSE) where he was the Graduate Program Chair for the Engineering Education Systems & Design (EESD) Ph.D. Program. He is currently a Deputy Editor for the Journal of Engineering Education and co-maintains the Engineering Education Community Resource wiki. Additional career highlights include serving as Chair of the Research in Engineering Education Network (REEN), visiting École Nationale Supérieure des Mines in Rabat, Morocco as a Fulbright Specialist, receiving an FSE Top 5% Teaching Award, receiving an ASEE Educational Research and Methods Division Apprentice Faculty Award, receiving a Frontiers in Education New Faculty Award, and being named an ASEE Fellow.

WIP: Teaching practices assessment tools as the foundation for identifying entrepreneurial education best practices

Abstract

Given the central role of engineering in national economic development, it is expected that the next generation of engineers must be prepared to work in a global context by coupling their traditional engineering skillset with an entrepreneurial mindset (EM) which is a collection of mental habits that foster curiosity, the ability to make connections, and the ability to create value when engaging with engineering problems. To best support the growth of an EM in engineering students, researchers have begun to design and implement teaching practices geared towards instilling this mindset in their students. However, there is still a dearth of research on assessing teaching practices that provide support for integrating EM into engineering courses. Thus, this work in progress reports the initial efforts to design an engineering-specific teaching practices assessment tool to serve in a larger project that addresses engineering teaching practices that infused EM mindset EM development. We conducted a literature review of STEM teaching practices assessment instruments to identify potential instruments that could serve as the foundation for our EM-infused engineering-specific teaching practices assessment tool. To cover the landscape of STEM education literature, an education-focused database and a multidisciplinary database focused on STEM education were searched using a combination of keywords logically organized with Boolean operators. The initial results from the database searches consisted of 158 peer-reviewed publications. After the selection process, 13 papers reporting teaching practices were identified. This literature review study listed the teaching practice assessment instruments reported in the selected documents and discussed their applicability to EM engineering teaching practices assessment. Comparing the types of teaching practice assessments, we identified that self-reporting teaching inventories offer a low-resource (personnel and time) alternative to assess teaching practices through the lens of the instructor. Ultimately, this study leveraged existing research on STEM teaching practice assessment tools to develop one that furthers the integration of EM in engineering education.

Introduction

In today's world, the continuous advancement of society's needs and technology has led to calls for engineers to possess more than just technical engineering skills. They must have skills that better prepare them for serving society, such as cultural competency [1] and communication skills [2] along with an understanding of their social and economic impact [3]. One way to achieve this end is by teaching students to harbor an Entrepreneurial Mindset (EM). This may be accomplished in a range of ways, and one such way is via collaboration with the Kern Entrepreneurial Engineering Network (KEEN) [4]. KEEN defines EM to be a collection of mental habits and attitudes that inform one's approach to problem solving and value creation for society [4]. Teaching students to harbor EM is done via Entrepreneurial Minded Learning (EML) and the 3Cs: Curiosity, Connections, and Creating Value [4].

Teaching assessment can provide structure for instruction and support of student learning in the classroom [5]. These assessments have shown student improvement with metacognitive functions, student outcome, student achievement and student motivation [5]. Teachers can use assessments as feedback to modify their teaching and provide students with feedback [6]. Teaching can provide students with individualized learning and enable tailored learning through feedback [6]. However, to enhance student learning through assessment, implantation of such assessment in classroom must be done properly; in many cases guidance to teachers can be limited and can negatively impact the classroom [6].

To address the need to support engineering students in developing an entrepreneurial mindset, in 2017, our institution started using the KEEN 3C's framework to implement EM Learning in the First-Year Engineering Program [7] and created EM-related professional development opportunities for instructors [8]. To standardize the assessment in the courses fomenting students' EM, our research group developed the Entrepreneurial Mindset Learning Outcomes (EMLO) and direct and indirect student EM assessment tools [9], [10]. At the same time, our research group highlighted the critical need to develop a robust teaching practices assessment tool to complement the ongoing efforts of incorporating EM into engineering courses, ensuring systematic evaluation and effective integration.

Thus, this work in progress reports the initial efforts to design an engineering-specific teaching practices assessment tool for a larger project investigating effective teaching practices for engineering students' EM development. A literature review was performed to identify potential teaching practices assessment instruments to be coupled to the 3C's indirect assessment tools or identify critical aspects of literature-reported instruments to design/adapt a new EM-based teaching practices assessment instrument. In this literature review study, we aimed to compile a list of instruments and discuss their applicability to develop an EM engineering teaching practices assessment that could be used in the STEM education field.

Methods

We conducted a literature review to identify in the STEM literature which teaching practices assessment tools have reported. A literature review can be described as an investigation that "provides an examination of current literature covering a wide range of subjects at various levels of completeness and comprehensiveness." [11] p. 94. Snyder [12] compiled a set of guiding questions organized in four phases (design, conduct, analysis, and structuring and writing the review) to support the development of the literature review. We use these guideline questions to conduct this literature review.

Questions referent to phase 1 (design) addressed the review's scope, justification, and searching strategies (e.g., search terms, databases, inclusion and exclusion criteria). Phase 2 (conduct) referred to practical procedures such as methods adjustments, documentation, and quality of the search and selection process. Phase 3 (analysis) prompted questions related to the information and focus of the review, reviewing team alignment, and reporting. Phase 4 (structuring and writing the review) referred to the review quality criteria. The following sections will address each of these phases and describe our investigation procedures.

1. Phase 1 – Design

Based on our goal of identifying and comparing teaching practices assessment tools reported in the STEM education field, we first needed to define teaching practices assessment in the context of this literature review. The term assessment was conceptualized based on Baker et al. [13], which defined assessment as "a systematic method of gaining a sample of information about people or programs […] to draw inferences about examinees' knowledge, characteristics, or propensities." (p. 96). In this study, a teaching practices assessment tool referred to any method (e.g., survey, observation, self-evaluation) of acquiring information on a specific teaching practice related to its effectiveness. Considering the diversity of context in teaching practices could be assessed, we scoped the literature review to STEM higher education.

In the context of STEM education, we used four databases simultaneously to cover the landscape of literature in education and STEM. The databases chosen were (1) the Education Resources Information Center (ERIC) and (2) Education Full Text, which are online databases focused on educational research; (3) Scopus, an interdisciplinary online database; and (4) the IEEE Xplore, which gathers engineering research specifically. These four databases provided a range of publications venues that allowed us to cover a broad and diverse number of papers. A search string was created to search for papers in these three databases. The search string was developed in multiple iterations to cover how teaching practices assessment tools could be named (e.g., inventories, surveys, and questionnaires). An initial search was performed to identify key terms used in teaching assessment research. From this initial search, a list of terms was identified. We used these terms to construct the following search string: *"teaching practice* instrument" or "classroom practice* instrument" or "teaching practice* surv*" or "classroom practice* surv*" or "teaching practice* inventor*" or "classroom practice* inventor*"or "teaching practice* question*" or "classroom practice* question*."* We used this search string on document abstracts to improve the search and scope of the number of search hits. In the Scopus and IEEE Xplore search, we needed to change the string to fit searching string constraints of the databases.

After searching and identifying papers that matched the search string, we conducted a selection process of sorting documents based on the following inclusion/exclusion criteria. The first criterion included papers written in English to streamline reviewers' selection and avoid translation issues or misconceptions after translation. The second criterion sorted papers based on their reviewing process. Only peer-reviewed papers were included for screening and revision. Peer-reviewed papers have passed through multiple stages of review, which can enhance their reliability. The third criterion referred to the content of the papers. We are focused on peer-reviewed educational studies that explicitly contain evidence of teaching assessment tools such as development, validation, and application of teaching practices assessment tools in STEM education in K-12 or K-16 levels. The processes of inclusion/exclusion, revision, and reporting conducted by our team are further discussed in the following section.

2. Phase 2 – Conduct

The team was composed of researchers with different backgrounds and a varied level of education, including engineering associate faculty, postdoctoral scholars, PhD students, and undergraduates. The literature review inclusion/exclusion process, data condensation, and summarization were mainly conducted by the first three authors of this paper. The first author is an international Engineering Education PhD candidate with experience in faculty educational development research and the development of materials to support faculty teaching issues. He contributes to the review process through a holistic perception of teaching rather than practical. The undergraduate author is a third-year biomedical engineering major with experience in the analysis of the sense of belonging in the first-year engineering class and analysis of technical communication feedback. She contributes to the review process from a student perspective rather than a teaching perspective.

The inclusion/exclusion and reviewing process was conducted by the same authors previously noted. We used a literature review management tool called Covidence.org to facilitate storing and comparing documents. All papers were uploaded to the management tool, and for each phase of paper selection, each of the three reviewers screened the paper and voted for papers to be excluded or included. This process was carried out in two rounds. During the process, the authors met weekly to discuss questions regarding the inclusion/exclusion of specific papers and to report progress. After applying the inclusion criteria (based on the consensus of the three researchers), we initially selected (n = 95) studies. In the second round, as we read through the studies in detail, we included papers that centered their discussion on the development or application of teaching practices. The following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart in Figure 1 illustrates the number of papers excluded in each round and the reasons for the exclusion in bullet points. The information from each of the included papers is compiled in Appendix A.

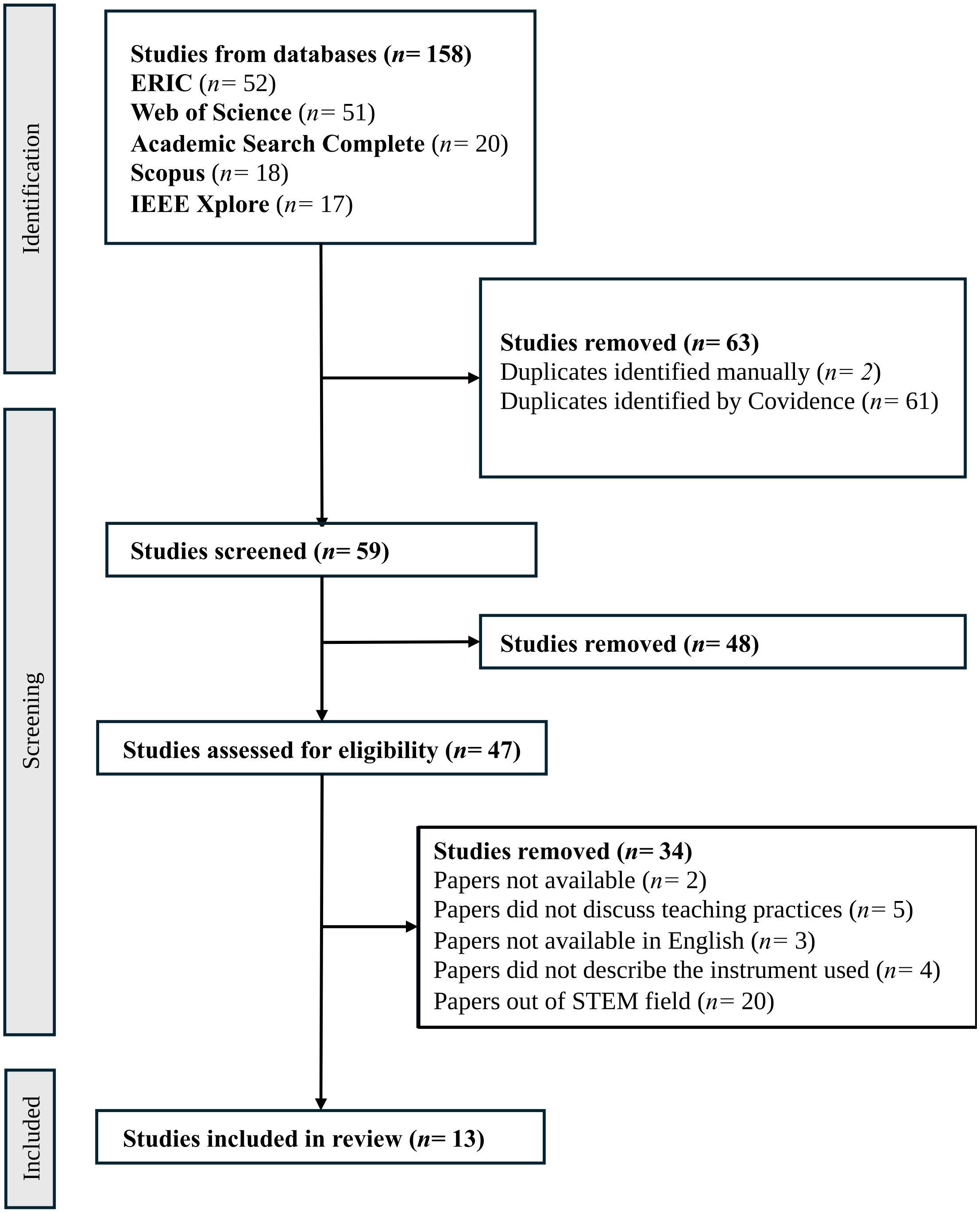

Figure 1 – PRISMA workflow

3. Phase 3 – Analysis

The final 13 papers included were thoroughly reviewed, and we compiled information regarding discipline, the type of instrument used to assess teaching practices, the level of education, and which elements of the instrument could be used to develop an EM teaching practices assessment tool. The authors looked collaboratively for similarities among the instruments reported, such as the frequency of use of a specific instrument or framework or any critical aspects across all teaching practice instruments, such as instrument sections, questions, or terms.

Results and Discussions

In this section, we synthesized the literature review data, describing the frequency of specific instruments used to assess teaching practices in STEM, which domains of teaching practices are highlighted by the identified instruments, and discussed the potential resource requirements of the most frequent instruments in the literature we covered. We also discussed which instruments show potential applicability to be adapted to assessing EM engineering teaching practices. The list of papers is compiled in Appendix A.

1. Identifying types of assessment tools used in STEM education

Among the selected 13 papers, 12 papers described either the validation or the application of previously validated instruments in STEM education, and one compared different classroom observation instruments. Twelve different instruments were described in the papers reviewed. A list of these instruments and their typology is presented in Appendix A. We identified three types of instruments reported in the literature: classroom observation, surveys, and inventories.

Inventories: Inventories were defined as a list of practices organized to identify which instructors use more frequently in the list. Inventories are not designed to assess teaching practices directly but serve as a tool to characterize classroom practices. Inventory results can be analyzed using a practical teaching framework that differentiates effective practices among the list of practices in the inventory. Seven papers reported using an inventory in the process of assessing teaching practices. The results indicated a trend for using inventories, and The Wieman and Gilbert's [14] Teaching Practices Inventory (TPI) was the most frequently used by investigators to assess teaching practices in the STEM field. The TPI was initially designed to cover a broader range of STEM teaching practices in a time-effective way [14], and this time-effective characteristic of the TPI can be the reason for its wide application in STEM higher education teaching practices assessment research. Considering that time is frequently reported as one of the most essential resources for faculty [15], identifying an instrument that provides a quick determination of STEM teaching practices can be critical to implementing an assessment investigation. Besides the time argument, papers that used TPI justified their decision based on its self-assessment characteristic that could allow participants to reflect on their teaching practices (e.g., [16]). Redding et al. [17] justified the use of TPI because it provided a general enough framework to be applied across different STEM disciplines while being specific enough to drive meaningful action, which is necessary to influence the implementation of high-impact teaching practices.

Surveys: Surveys were operationalized as instruments organized in sets of questions regarding a specific topic, designed to measure individuals' views, interests, traits, practices, or personal information [18]. Four papers reported using surveys to assess instructors' teaching practices. An example of survey applicability in teaching practice assessments is provided by Bober et al. [19], who used the Instructional Methods Survey to assess the frequency of educational technology use in the classroom and the instructors' beliefs related to learner-centered instruction. Houseknecht et al. [20] adopted Walters et al.'s [21] Postsecondary Instructional Practices Survey (PIPS) to measure the teaching practices of university chemistry instructors. Compared to the inventory, the survey instruments are designed over a theoretical framework and can be organized into factors related to the assessed constructs. While inventories can characterize classroom teaching, surveys can be more specific and include constructs such as self-efficacy or teaching beliefs in their design.

Classroom Observation: Classroom observation instruments referred to the set of observation protocols to be performed in the classroom settings to characterize and assess teaching practices. Two papers described classroom observation instruments. Roehrig et al. [22] used classroom observation to assess the impact of an educational development program for early childhood in the midwestern US. They employed an instrument entitled Classroom Assessment Scoring System (CLASS), which was previously validated and widely used in the K-12 space. Asgari et al. [23] developed a study to compare three classroom observation instruments widely implemented in STEM higher education. They compared the (1) Classroom Observation Protocol for Undergraduate STEM (COPUS) [24], (2) Practical Observation Rubric to Assess Active Learning (PORTAAL) [25], and (3) Decibel Analysis for Research in Teaching (DART) [26] regarding the steps to implement each of the instruments (e.g., surveying instructions, training personnel, coding, and instructors feedback). Their results indicated that PORTAAL provided more information regarding active learning practices, but it was also the instrument that required the most resources to implement. In those criteria, PORTAAL was followed by COPUS and DARTT, respectively.

Compared to inventories and surveys, these classroom observation assessment instruments offer an objective assessment, given that it is performed in the classroom and can be structured by protocol instead of self-reported by the instructor. Asgari et al. [23] recommended considering the desired outcome and the resources needed to use classroom observation protocols (e.g., personal and training resources). Classroom Observations can be time-consuming, requiring the research team to invest in personnel and training related to data collection, analysis, and interpretation [27]. It can be more complex in multi-institutional settings because observation will be performed in different contexts, requiring the team to ensure alignment at each process step or to have a data-collection team travel to multiple sites.

2. Domains of teaching practices represented in reported instruments

Each instrument reported in the reviewed papers aimed to assess teaching practices in different settings (e.g., discipline, type of course, institution). Because of the context in which these instruments were designed and implemented, various aspects of teaching were highlighted in the assessment process. These specific aspects could be grouped into topics, sections or sets of concepts related to teaching, which we operationalized as the domains of teaching. Examples of the domains targeted in the reviewed instruments are provided in Table 1. The core domains we identified permeating most of the instruments reviewed are related to instructional design (e.g., learning objectives, instructional sequence, materials provided, assessment strategies) and its alignment with student-student and student-instructor interactions. It provides a foundation to reflect which elements could be imported to design or adapt an EM-focus teaching practices assessment instrument. Given that the EM framework developed by the KEEN centers the discussions within the 3Cs, which are broader constructs, the EM teaching practices assessment instrument must focus on specific aspects of teaching instead of approaching the assessment generally. For example, the assessment of EM teaching practices should start with evaluating the aspects of instructional design to identify if the learning experiences are designed to promote EM.

Table 1 – Examples of teaching concepts covered in the reviewed instruments

Paper Title	Domains of teaching covered in the instrument
A Better Way to Evaluate Undergraduate Teaching	• Course information provided • In-class features and activities • Assignments • Feedback and testing • The training and guidance of teaching assistants, collaboration
Instructional practices of teachers enrolled in education technology and general education programs	• Instructional design • Learned-centered instruction • Assessment • Instructional alignment and media and technology
We Look More, Listen More, Notice More: Impact of Sustained Professional Development on Head Start Teachers' Inquiry-Based and Culturally-Relevant Science Teaching Practices	• Emotional support (positive/negative climate, teacher sensitivity, regard for students' perspective) • Classroom organization (behavior management, productivity, instructional learning format) • Instructional support (concept development, quality of feedback, language modeling).
Teacher Tech-Creativity Fostering Behaviour as Determinant of Primary School Mathematics Teacher Classroom Practices	• Teacher clarity • Classroom discussion • Feedback • Formative assessment • Teacher-teacher collaboration

3. Potential application of existing teaching assessments to EM content

Considering the KEEN EM theoretical framework in development and comparing the three types of instruments identified in this literature review, inventories are a good option for identifying EM teaching practices. Compared to classroom observation instruments, inventories offer a more straightforward implementation, particularly in multi-site research, where training personnel at each institution would be required. Surveys could be used, but they would not characterize what instructors are doing in the classroom for EM development; they could be used as a complementary instrument to measure instructors' and students' beliefs. Inventories could be implemented to collect data regarding the type and frequency of EM teaching practices, which could serve to develop guidelines for effective EM teaching and as additional evidence to the KEEN EM theoretical framework.

While the instructional design assessment provides a broad understanding of what is expected from the course, it is also necessary to investigate the practical aspects of teaching. This practical aspect is covered by some of the instruments (e.g., the Teaching Practices Inventory and The Mathematics Teacher Classroom Practice Inventory) in terms of in-class activities, assignments, classroom discussions, and instructor clarity when presenting information. Some authors provided a list of effective teaching practices that could be used as an initial inventory to adapt an EM-focus instrument. For example, Houseknecht et al. [20] listed Flipped classrooms, Just-in-time teaching, peer instruction, and formative assessment as evidence-based instructional Practices.

Regarding the implementation, inventories are presented as an easier option to perform the initial characterization of teaching practices and have been reported in the literature as an alternative for teaching practices research. The Wieman and Gilbert's [14] TPI, the most frequently used instrument in the reviewed papers, also provided a list of effective teaching practices that can be used to design an EM teaching practices assessment instrument. It has been widely used in STEM teaching practices assessment research and encompasses a set of teaching practices that are similar to what has been performed by STEM instructors in the US context. Because of that, the TPI can offer a potential structure to develop an EM-specific teaching practices inventory that leverages the TPI list of teaching practices with additional EM-specific teaching practices that those general teaching practice assessment tools may not have covered.

Conclusions

This work-in-progress reported the initial efforts to identify examples of STEM teaching practices assessment instruments that could help develop an EM-teaching practices assessment tool in engineering undergraduate courses. We conducted a literature review of teaching assessment tools. We discussed the most frequently used assessment tools, and which domains of those instruments could be used to develop an EM-teaching practices assessment tool. Our findings indicate that teaching inventories are widely used and recommended in STEM education and research due to their time efficiency and effectiveness in identifying teaching practices employed by instructors, especially when compared to other assessment tools like surveys and classroom observations. Besides that, our study also identified that Wieman and Gilbert's [14] TPI was widely adopted by reviewed papers, indicating that it can provide a reasonable frame to orient the development of a new EM-teaching practices assessment tool and serves as the basis of our future work. Specifically to the KEEN EM framework, which has constructs being tested and further developed, the TPI offers an assessment structure that can be initially used to characterize instructors' EM teaching practices and later assess the TPI results via triangulation with other assessment instruments. To develop the TPI to EM teaching assessment, our work suggests that other aspects of teaching, such as instructional design elements (e.g., learning objectives, instructional sequence, and instruction clarity), should be included in its structure. This recommendation should also serve as a foundation for educators to think about entrepreneurship education holistically, in contrast to an isolated aspect of student development. It should be aligned and embedded in the instructional design process. At the same time, EM-specific teaching practices should be identified via literature review, experts, professional developers, and practitioners' feedback to complement the existing list of practices provided in the TPI. This collectively supports our future work in the development of an EM-oriented assessment based on the TPI. In conclusion, this literature review serves as a valuable resource, leveraging the expertise of KEEN to guide the development and validation of an EM-teaching practices inventory, which aims to assess and support the integration of EM teaching practices into engineering courses.

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APPENDIX A – List of Reviewed Papers

Paper Title	Authors	Year	Journal	Type of Instrument	Educational Level	Level and Discipline	Instrument Name
COPUS, PORTAAL, or DART? Classroom Observation Tool Comparison From the Instructor User's Perspective	Asgari et al. [23]	2021	Frontiers in Education	Observation	Higher Education	Biology	(1) Classroom Observation Protocol for Undergraduate STEM (2) Practical Observation Rubric to (3) Assess Active Learning Decibel Analysis for Research in Teaching
Barriers to Change: Social Network Interactions Not Sufficient for Diffusion of High-Impact Practices in STEM Teaching	Reding et al. [17]	2022	Education Sciences	Inventory	Higher Education	STEM	Teaching Practices Inventory

Current Teaching Methods in STEM Departments -- A Road Map for Fundamental University Educational Reform: Evidence from Lebanon	Sabat et al. [28]	2022	Journal of Applied Research in Higher Education	Inventory	Higher Education	STEM	Teaching Practices Inventory
A Better Way to Evaluate Undergraduate Teaching	Wieman [29]	2015	Change: The Magazine of Higher Learning	Inventory	Higher Education	Math and Sciences	Teaching Practices Inventory
Instructional practices of teachers enrolled in education technlogy and general education programs	Bober et al. [19]	1998	Education Technology Research and Development	Survey	Higher Education	Educational Technology and Education	Instructional Methods Survey
Laboratory Medicine Education in United-States Medical-Schools	Gottfried et al. [30]	1993	American Journal of Clinical Pathology	Survey	Higher Education	Medicine	Not defined

Effectiveness of the Active Learning in Organic Chemistry Faculty Workshops	Houseknecht et al. [20]	2020	Chemistry Education Research and Practice	Survey	Higher Education	Chemistry	Postsecondary Instructional Practices Survey
Knowledge and motivation as mediators in mathematics teaching practice: the case of drawn models for fraction arithmetic.	Jacobson and Izsák [31]	2015	Journal of Mathematics Teacher Education	Survey	K-12	Math	Diagnosing Teachers' Multiplicative Reasoning (DMTR) Fraction Survey
We Look More, Listen More, Notice More: Impact of Sustained Professional Development on Head Start Teachers' Inquiry-Based and Culturally-Relevant Science	Roehrig et al. [22]	2011	Journal of Science Education & Technology	Observation	K-12	Science	CLASS (Classroom Assessment Scoring System) Observation Protocol

Teaching Practices							
Using Teaching Practices Inventory to Evaluate Mathematics Faculty Teaching Practices in Higher Education	Alsharif and Alamri [16]	2020	International Journal of Instruction	Inventory	Higher Education	Math	Teaching Practices Inventory
The adoption of student-centered teaching materials as a professional development experience for college faculty	Czajka and McConnell [32]	2019	International Journal of Science Education	Inventory	Higher Education	STEM	Teaching Practices Inventory
Teacher Tech-Creativity Fostering Behaviour as Determinant of Primary School Mathematics Teacher	Chianson-Akaa et al. [33]	2024	International Online Journal of Primary Education	Inventory	K-12	Math	The Mathematics Teacher Classroom Practice Inventory (MTCPI)

Classroom Practices							
Students' perception of teaching practice in an active learning environment	Dominguez and Zavala [34]	2019	ASEE Annual Conference and Exposition, Conference Proceedings	Inventory	Higher Education	Engineering	Teaching Practices Inventory – Adapted to Students