This document provides a comprehensive description of the professional preparation and development required to fully prepare teachers of engineering[1]. A preservice teacher preparation program should address all aspects of all standards over a student's four-year course of study. By contrast, a more time-constrained professional development opportunity for in-service teachers should focus deliberately on a subset of the standards (while aligning with complementary opportunities so that teachers receive, over time, professional development that addresses all aspects of all standards).

Nature, Content, and Practices of Engineering

Engineering is based on extensive bodies of knowledge. It is a unique disciplinary field, yet shares some features with science, technology, and mathematics. Engineering literacy requires understanding the fundamental nature, content, and practices of engineering, which may be organized into three categories.

Literacy in the category of **engineering design (ED)** requires an understanding that engineering:

1. Is inherently innovative and creative;
2. Requires critical thinking and problem solving;
3. Is collaborative and team-oriented;
4. Involves solving problems via the engineering design process (*e.g.*, involving design under constraints, iterative design, optimization, improvement);
5. Requires the combination of engineering subject matter knowledge with engineering practices;
6. Involves systems thinking (*e.g.*, considering solutions as they are a part of larger systems);
7. Uses failure as a learning experience (*e.g.*, when designed solutions fail, engineers learn from this failure and improve based on this new knowledge);
8. Assumes that there are multiple possible solutions to one problem; and
9. Involves multiple means of communicating outcomes (*e.g.*, technical reports, graphs, data, models, recommendations).

Literacy in the category of **engineering careers (EC)** requires an understanding that:

10. Engineering includes multiple areas of specialization (*e.g.*, mechanical, electrical, petroleum, civil, biomedical, aerospace, environmental, industrial); and
11. Engineering career pathways are accessible via a variety of educational routes.

Literacy in the category of **engineering and society (ES)** requires an understanding that engineering:

12. Has a long and rich history;
13. Is relevant to current events;
14. Generates technological solutions that add value to society, yet may also have negative (and largely unintended) consequences for society; and
15. Is influenced by cultures and societies.

Standards for Professional Development for Teachers of Engineering

The following standards are intended to ensure teachers develop engineering literacy (as defined above) sufficient to teach engineering to students at the appropriate level.

Standard A: Engineering Content and Practices

Professional development for teachers of engineering should address the fundamental nature, content, and practices of engineering as defined above. To promote literacy in the category of **engineering design**, it should:

1. Engage teams of participants in authentic engineering practices and processes (*i.e.*, participating in the engineering design process as initiated by a design challenge statement, through at least one improvement cycle, and involving communication of results);
2. Introduce participants to tools that enable success in engineering; such tools include engineering notebooks, simple tools (*e.g.*, rulers), and more sophisticated technologies (*e.g.*, computer probeware and software, digital multimeters);

1 Teachers of engineering are all teachers who (1) are required to teach engineering learning standards (*NB*, under the Next Generation Science Standards this includes all elementary school teachers and secondary teachers of science) or (2) employ engineering as a context for learning in other subjects.

3. Introduce participants to strategies that enable success in engineering; key strategies include engaging in teams, asking questions, communication about design, and carefully documenting work;
4. Encourage participants to reflect on multiple experiences with the engineering design process, whether these have occurred within or outside the context of the current professional development opportunity, to reinforce learning about engineering content and practices; and
5. Enable participants to compare design in engineering to design in other fields (*e.g.*, fashion, architecture, art).

To promote literacy in the category of **engineering careers**, such professional development should:

6. Provide opportunities for participants to learn about engineering fields and professions;
7. Engage participants in comparing engineering with non-engineering content areas (*e.g.*, mathematics, science, social studies, English language arts, the arts, technology education);
8. Engage participants in comparing classroom-based engineering experiences with professional engineering practice; and
9. Provide opportunities for educators to learn about the pre-collegiate and collegiate academic preparation required for engineering careers.

To promote literacy in the category of **engineering and society**, such professional development should:

10. Provide opportunities for participants to explore the work of engineers and their contributions to society, as well as ways in which some engineered solutions have caused societal challenges.

Standard B: Pedagogical Content Knowledge for Teaching Engineering

Professional development for teachers of engineering should emphasize engineering pedagogical content knowledge. It should:

1. Engage participants in exploring teaching and learning in engineering and how it is similar to, and different from, teaching and learning in science and/or mathematics;
2. Introduce participants to effective classroom management strategies for enabling learning in engineering;
3. Foster participants' ability to develop design challenges that are appropriate for their student population, teaching environments, and/or local community;
4. Facilitate participants' reflection upon their own teaching practice and encourage participants to seek feedback from others to refine and optimize their engineering teaching practice; and
5. Promote and support participants' engagement with engineering mentors who can, in turn, support participants' teaching of engineering through a variety of approaches (*e.g.*, field experiences, field trips, internships, collaborations, classroom visits).

Standard C: Engineering as a Context for Teaching and Learning

Professional development for teachers of engineering should make clear how engineering design and problem solving offer a context for teaching standards of learning in science, mathematics, language arts, reading, and other subjects. It should:

1. Enable participants to explore research that demonstrates how using engineering design and problem solving as a context for learning improves students' critical thinking skills and academic achievement;
2. Engage participants in engineering design challenges that require horizontal integration with non-engineering content (*e.g.*, mathematics, science, social studies, English language arts, the arts, technology education);
3. Draw attention to the way in which engineering design and problem solving reinforce skills (*e.g.*, 21st century skills such as creativity, communication, critical thinking, and collaboration) and practices (*e.g.*, modeling, data analysis, and presentation) that are relevant to many fields; and
4. Encourage participants to integrate engineering into the existing curriculum.

Standard D: Curriculum and Assessment

Professional development for teachers of engineering should empower teachers to identify appropriate curriculum, instructional materials, and assessment methods. It should:

1. Enable participants to identify engineering curriculum that is developmentally, instructionally, and cognitively appropriate for their students;

2. Engage participants in evaluating the potential of engineering curriculum to address one or more sets of student learning standards (*e.g.*, ITEEA learning standards, Next Generation Science Standards, state standards);
3. Engage participants in evaluating the potential of engineering curriculum to support a particular set of engineering learning objectives;
4. Engage participants in evaluating the adaptability of engineering curriculum to local conditions (*e.g.*, scheduling/timing, emphasis on content/methods, cultural context, similarity to other activities in an existing curriculum);
5. Engage participants in evaluating the available teacher support for a particular engineering curriculum;
6. Engage participants in examining the authenticity and appropriateness of formative and summative assessments embedded in a curriculum; and
7. Demonstrate connections and alignment between engineering curriculum, instruction, learning, and assessment.

Standard E: Alignment to Research, Standards, and Educational Practices

Professional development for teachers of engineering should be aligned to current educational research and student learning standards. It should:

1. Be developed and refined in collaboration with experts in the fields of engineering, engineering pedagogy, and teacher professional development;
2. Be developed and refined in collaboration with stakeholders (*e.g.*, state education agency personnel, school administrators, teachers);
3. Enable participants to experience the curriculum that they will teach;
4. Model effective engineering teaching practices;
5. Employ differentiated instruction techniques;
6. Be guided by formative assessment;
7. Encourage risk-taking by participants;
8. Be longitudinal; and
9. Evolve through a process of continuous improvement that employs ongoing evaluation, assessment and revision.