ENGINEERING CHANGE LAB USA

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LICENSURE MODELS FOR THE FOURTH INDUSTRIAL REVOLUTION

Summit 10 Report
Dec 16, 2020

LICENSURE MODELS FOR THE FOURTH INDUSTRIAL REVOLUTION

ECL-USA Summit 10 • Dec 16, 2020

Overview

The disruptive technologies of the Fourth Industrial Revolution are blurring the boundaries of the traditional practice of engineering and challenging the traditional models of licensure for engineers. Engineering Change Lab – USA (ECL-USA) Summit 10, presented in partnership with the National Society of Professional Engineers and the National Council of Examiners for Engineering and Surveying, explored the future of licensure for engineering and the role licensure and regulatory bodies can play in ensuring that engineers and organizations engaged in the development of the technologies of the Fourth Industrial Revolution act in the public interest. Discussions at Summit 10 demonstrated a clear need for engineering licensure models to adapt to these transformational developments in a manner that will protect the public and guide engineers to practice as stewards of technology and nature on behalf of society.

PROVOCATEURS

Patty Mamola

EXECUTIVE DIRECTOR, NEVADA STATE BOARD OF PROFESSIONAL ENGINEERS AND LAND SURVEYORS

Patty is a licensed professional civil engineer in Nevada with private and public-sector engineering experience and expertise in construction management. Patty served nine years on the Nevada Board of Engineers and Land Surveyors. She is a past-president of NCEES currently serving as Chair of the APEC Engineer Agreement, one of the international mobility agreements of the International Engineering Alliance facilitating mobility for professional engineers.

Lance Kinney

EXECUTIVE DIRECTOR, TEXAS BOARD OF PROFESSIONAL ENGINEERS AND LAND SURVEYORS

Dr. Kinney is the Executive Director of the Texas Board of Professional Engineers and Land Surveyors. He has been with the Board for over 18 years and is responsible for all agency programs and activities, including legislative, rule, budget, and policy issues, and represents the Board at statewide, national, and international functions.

Caitlin Kenney

INTERNATIONAL SYSTEMS MANAGEMENT CORP.

Caitlin Kenney, PE is an Industrial & Systems Engineer for International Systems Management Corp. She has over ten years of experience supporting DoD projects, currently supporting software development and technology insertion for the US Navy. Caitlin is a member of the Council for Industrial and Systems Engineering and a volunteer with NCEES. She holds a BS in Industrial Engineering from Northeastern University; MS in Systems Engineer from University of Maryland; and is currently pursuing a PhD in Civil Engineering from University of Maryland.

Mark Abbott

MANAGING DIRECTOR, ENGINEERING CHANGE LAB - CANADA

Mark currently serves as the Managing Director of the Engineering Change Lab Canada, which is a catalyst for evolving the engineering community to reach its full potential as stewards of technology for the benefit of all. Over the past five years, over 150 organizations and 350+ individual leaders (CEOs, VPs, Deans, Directors) have collaborated using the Lab's platform, advancing understanding and action to evolve engineering. Mark previously spent five years with EWB Canada and 14 years with a heavy industrial consulting engineering firm based in Vancouver.

Timothy Jacobs

FOUNDING INTERIM DEPARTMENT HEAD OF THE DEPARTMENT OF MULTI-DISCIPLINARY ENGINEERING, TEXAS A&M UNIVERSITY

Dr. Timothy Jacobs is professor and Steve Brauer, Jr. '02 Faculty Fellow of the Department of Mechanical Engineering at Texas A&M University. He also serves as Founding Interim Department Head of the Department of Multi-Disciplinary Engineering. Dr. Jacobs has overseen inter-disciplinary engineering efforts in the College of Engineering since January 2017, growing the program from less than 30 students to now over 170 students across six inter-disciplinary engineering degree programs. Dr. Jacobs is a multi-award-winning instructor and a Fellow of the American Society of Mechanical Engineers.

Provocations

LICENSURE CHALLENGES IN THE FOURTH INDUSTRIAL REVOLUTION

PATTY MAMOLA, P.E.
EXECUTIVE DIRECTOR, NEVADA STATE BOARD OF PROFESSIONAL ENGINEERS AND LAND SURVEYORS

LANCE KINNEY, P.E.
EXECUTIVE DIRECTOR, TEXAS BOARD OF PROFESSIONAL ENGINEERS AND SURVEYORS

Patty Mamola and Lance Kinney are Executive Directors of the State Licensing Boards in Nevada and Texas, respectively. Since the inception of ECL-USA, they have advocated for the importance of considering licensure models in our exploration of the future of engineering. In their introductory provocation, Patty and Lance challenged participants to focus on the core purpose of licensure, the protection of the public, and to consider the future of engineering regulation (licensure) in the face of changes in education, legislation, technology, public perception and expectations, and changes in the practice of engineering.

Education
Emergence of new engineering disciplines and multi-disciplinary degrees driven by industry and student demand.

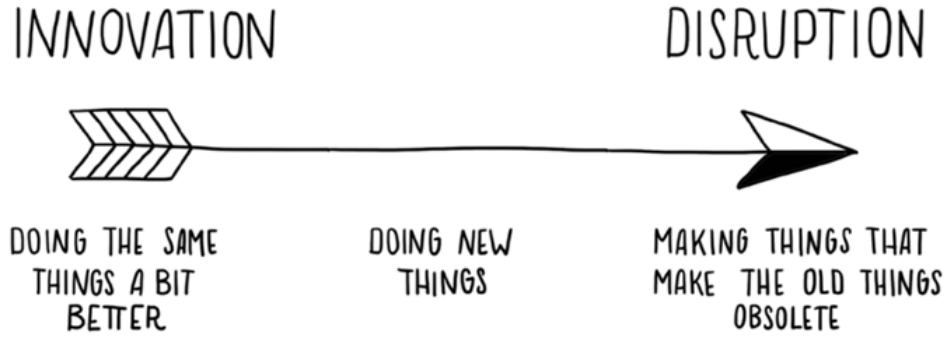
Legislation
Increasing focus by legislators on reducing barriers to entry and easing the portability of licenses across state lines.

Public Perception and Expectations
Lack of understanding by the public of what engineers do, of the fact that not all engineers need to be licensed, and of the differences between software developers and licensed engineers.

Technology
Artificial intelligence, machine learning, data analysis, the Internet of Things, and other technologies often developed by non-engineers increasingly being utilized in engineering solutions.

Engineering Practice
Complex, inter-disciplinary projects; imperative for more sustainable, resilient designs; increasing stakeholder and public involvement; integration of emerging technologies into projects.

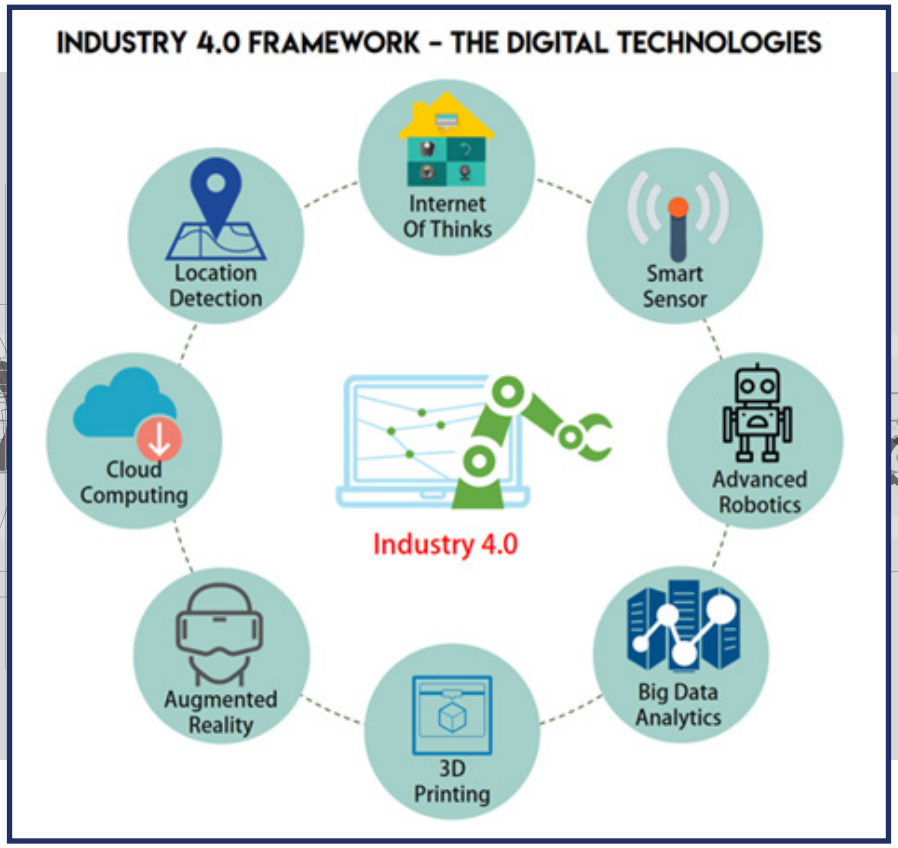
Lance and Patty encouraged participants not to get caught up in minor modifications to the current processes of licensure, but to understand that transformational disruption of traditional models may be needed. Future licensure models will need to address accountability for errors or failures related to emerging technologies, individual vs. system ethics, who should be regulated, who should be licensed, and who should be doing the regulating and licensing.



LICENSURE & INDUSTRY 4.0

CAITLIN KENNEY, P.E.
INTERNATIONAL SYSTEMS MANAGEMENT CORPORATION

Caitlin Kenney brought the perspective of engineering practice in industry to Summit 10. She described the emerging technologies of Industry 4.0, technologies that are all about automation of traditional manufacturing and industrial systems to create inter-connected and "smarter" systems. These technologies are resulting in new responsibilities for engineers involved in their creation and implementation. She emphasized that the impacts of emerging technologies extend beyond manufacturing and industrial engineering, impacting all engineering disciplines. These complex systems mean that there are "more humans in the loop than ever before and there are infinite opportunities for things to go wrong."



Caitlin emphasized that systems thinking is key to engineers' new responsibilities, thinking that extends beyond our individual work to developing a deep understanding of the impacts of products on the public and that incorporates the protection of users and user data. She emphasized that Industry 4.0 is exposing gaps in the licensure system and that the licensure systems needs to be agile and adaptable, accommodating to inter-disciplinary engineering, focused on the imperative of continuous learning, and applicable to working with non-engineering, technological disciplines.

Group Exercise I – Exploring Regulatory Challenges

The challenges of the Fourth Industrial Revolution are revealing the need for licensure to encompass a broader definition of engineering practice and engineering ethics. In the first group exercise of Summit 10, participants looked at emerging technologies and licensure through the lens of both micro-ethics and macro-ethics.

Micro-ethical issues relate to the individual engineer and/or license holder and their internal relation to the licensing board and the engineering profession.

Macro-ethical issues relate to the collective social responsibility of the profession and to societal decisions about technology.

From: "Ways of Thinking about and Teaching Ethical Problem Solving," Science and Engineering Ethics (2005), Herkert, J. R.

Participants were asked to look at a list of real-world failure scenarios and categorize the scenarios as involving conventional versus emerging technologies, and as involving micro-ethics versus macro-ethics. Participants then discussed the regulatory challenges posed by the scenarios involving emerging technologies and macro-ethical considerations.

	Micro-Ethics	***Macro-Ethics***
Emerging Technologies		
Conventional Technologies		

21st Century Engineering Failure Scenarios

- A cyber-security vulnerability results in a power plant being taken down.
- A tech start-up distributes "smart" (internet-enabled) rental scooters across several major cities with no notification of or permits from the municipal governments.
- A bridge collapses because of an incorrect input into design software.
- Facial recognition software has difficulty identifying people with darker skin because training data was biased.
- Engineers pay kickbacks and cut corners on an infrastructure project under pressure from their company.
- A bridge collapses due to errors inherent in the design software produced by a major software developer for the industry.
- A car company uses a software cheat to circumvent environmental regulations.
- The design of a social network / news website enables misinformation that impacts an election.
- Senior scientists and engineers working for a blood testing start-up fail to make public their concerns about the efficacy of the testing technology and a lack of transparency about test results due to fear of being taken to court for violation of non-disclosure agreements and mis-use of trade secrets.
- A strain of genetically modified corn, approved for use in animal feed but not for human consumption, turns up in corn products made by a major food producer and sold to fast food chains. Subsequent buybacks, product recalls, and loss of exports run into hundreds of millions of dollars.
- City infrastructure is designed to isolate disadvantaged communities.
- An error in a software patch causes a plane to crash.
- Inadequate training and safety infractions contribute to a major freight train derailment and spill of hazardous materials into a pristine watershed.
- Information gained from virtual reality devices on how users respond to different stimuli (tracking eye movements, head positions, and monitoring emotional states) is collected without the users' permission and used to influence buying behaviors of social media users.
- An autonomous vehicle is involved in an accident resulting from an unforeseen condition.
- Over-reliance on artificial intelligence systems for monitoring and controlling operations and safety contributes to a major oil spill from an offshore drilling platform.
- "Smart city" cameras, sensors, and big data software and technologies disproportionately target urban minority communities for surveillance and arrest.
- Flooding occurs from failure of a dam designed based on traditional rainfall intensity / frequency standards.

The results of the discussions of the eight groups are summarized below.

GROUP 1 – Smart Scooters without Approval or Permits.

- Engineering involvement in the scooter company is unknown.
- Unclear regulatory path for a new technology like scooters.
- No mandate for P.E. involvement in the scooter company or on regulatory boards.
- Regulatory boards at the municipal level often lack qualified members to assist the public in understanding and evaluating new technologies.
- Elitist view of engineering is a dangerous path for licensure model.

GROUP 2 – Biases in Facial Recognition Software.

- How do you regulate software?
- Does the P.E. stamp signify approval of the software application?
- Software is developed by non-licensed technologists.
- Corporate liability?

GROUP 3 – Design of Social Network News Site Impacting Election.

- Censorship is an issue in regulation.
- Lots of questions around regulation versus free speech rights.
- Need more ethics training, but how do we regulate ethics?
- Who should be regulated- owner of platform or users?
- Ethical issues in emerging technologies are difficult due to impacts of human behavior.

GROUP 4 – Software Patch Causes Plane Crash.

- Licensure currently not required in either software development or aircraft manufacturing.
- Current licensure model is not capturing emerging technologies.

GROUP 5 – AV Involved in Accident Due to Unforeseen Condition.

- Body of knowledge is growing faster than regulation and industry associations can develop standards (i.e., AV's).
- Regulation is needed for emerging technologies, but how?
- National license may be a solution.

GROUP 6 – Over-reliance on AI for Monitoring Systems Contributes to Oil Spill.

- AI adds complexity to complexity.
- Tendency is to believe the computer.
- How can one PE be accountable for a project like an oil well that also involves AI?
- Team approach- multiple PE's accountable.
- Importance of life-cycle analysis- need to consider the long-term operations of facilities.

GROUP 7 – Smart City Technology Disproportionately Impacts Minority Communities.

- Smart City technologies are generally good, but application can be bad.
- Is the issue public safety or moral/ethical?
- Could translate to a public safety issue depending on public reaction.
- Considerations for licensure- performance-based models, continuing education related to emerging technologies.
- Are we equipped or trained to handle AI or other technology making decisions for people that could have undesirable outcomes and then how to determine the responsible party should something go wrong?

GROUP 8 – Virtual Reality Devices That Track Reactions to Stimuli Impacting Buyer Behavior.

- Consumer protection.
- Public understanding of technology- need to inform consumers and/or obtain permission.
- Ability for consumers to opt out.
- Current licensure models do not apply.

Consideration of these failure scenarios that involve emerging technologies combined with macro-ethical responsibilities produced common elements applicable to future models for engineering licensure.

	Blurring of the lines – consumers / users of technology, engineers / engineering disciplines, technology developers.
	Increasing application of emerging technologies, developed in unlicensed and unregulated industries, in public infrastructure.
	Need for industry standards for emerging technologies that can be referenced in licensure models.
	Consideration of the entire life cycle of a product or project is needed. Can this responsibility be subject to licensure?
	Importance of life-long learning for engineers.
	Potential advantages of licensure at a national level, rather than a state level.
	Rising importance of ethics as a component of licensure given that the examination model cannot keep up with rapid technological advancements.
	Learning from the medical profession about ethics- preventing harm and providing benefits (beneficence), avoiding the causation of harm (non-maleficence), supporting and respecting autonomous decisions (respect for autonomy), and fairly distributing benefits, risks, and costs (justice).
	Importance of education of the public about engineering and technology issues.
	Potential consideration of multiple levels of accountability in licensure.
	Need for multi-disciplinary licensure.
	Need for a licensure model that captures all engineers.

Provocations

LEARNING FROM ECL-CANADA / PROFESSIONAL ENGINEERS OF ONTARIO

MARK ABBOTT, P. ENG.
MANAGING DIRECTOR ENGINEERING CHANGE LAB - CANADA

Earlier in 2020, ECL-Canada collaborated with Professional Engineers Ontario (PEO) in a conference intended to "help enhance PEO's ability to protect the public interest within a rapidly changing world by supporting the development of a longer-term vision for the organization." Mark Abbott shared lessons learned from this conference.

To set the stage, Mark offered comparisons between the Canadian and American licensure models. A key difference is that licensure in Canada is self-regulated.

Mark characterized the conference as revealing that this is a "critical moment for engineering and engineering licensure," as demonstrated by three key points that emerged from the ECL-Canada / PEO conference.

NEED

Need for more critical reflection about the role of engineering in society along with a shared understanding of the meaning of engineering.

NEED

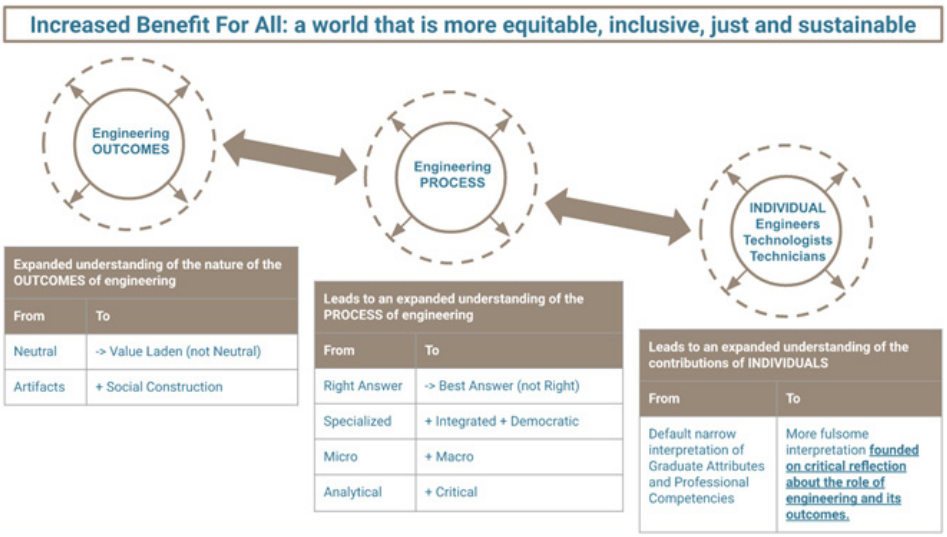
Need to break out of siloed thinking about engineering and embrace greater collaboration with other disciplines and with the public about the work of engineering.

NEED

Need to navigate value tensions to avoid both focused obsolescence or expansive disintegration. Focused obsolescence from a regulatory standpoint would mean focusing only on micro ethical issues associated with physical technologies. At the other extreme is the risk of expansive disintegration due to overreach in expanding the focus of regulation to macro-ethical and digital technologies. Regulatory organizations must grapple with this overarching polarity, while also addressing other related polarities such as:

- Depth vs. breadth of the regulatory value proposition;
- Stability vs. change (as they seek to evolve their value proposition);
- Organizational health vs. organizational impact (as they seek to evolve their operations); and
- Specialist expertise vs. lived experience (as they develop their human resources).

Mark summarized the future vision for engineering's contributions as based on broadening the view of the outcomes of engineering which shines the light on changes in processes needed and expands the skills that engineers need.



THE FUTURE OF ENGINEERING LICENSURE IN THE FACE OF CHANGING ENGINEERING EDUCATION

TIM JACOBS

FOUNDING INTERIM DEPARTMENT HEAD OF THE DEPARTMENT OF MULTI-DISCIPLINARY ENGINEERING, TEXAS A&M UNIVERSITY

Dr. Jacobs described the evolution of engineering education in teaching methods, student diversity, and accreditation. He emphasized that the need for interdisciplinary education is being driven by industry "blowing up the silo" that engineers should be educated in only one discipline. Engineering students are also increasingly diverse and are seeking different ways of thinking and different approaches to solving problems. Texas A&M has formalized this concept.

This shift to interdisciplinary learning means that the role of the professor is evolving to a coaching and guidance role and that learning environments are also becoming interdisciplinary. Accreditation has also changed from a checklist approach to a focus on outcomes. This has resulted in improvements in student learning.

Inter-disciplinary classroom at Texas A&M University

Texas A&M's multi-disciplinary program is offering innovative options for students to pursue non-traditional paths blending different disciplines. Their Bachelor of Science in Interdisciplinary Engineering enables students to self-select up to 58 of the required 128 credit hours of coursework from multiple engineering disciplines. Another unique aspect of Texas A&M's approach is their belief in the education of non-engineering students through offering a Minor in Engineering Concepts.

How do these students get licensed? The only current option is to pick a specialty for their exam. Will State Boards accept these types of engineering degrees? Is this the best option to protect society? One option that might provide greater value in protecting society would be to base licensure on a portfolio of work that demonstrates essential engineering skills. This approach puts lifelong learning front and center as an element of licensure.

Group Exercise II – Licensing Emerging Disciplines / Degrees

In the second group exercise, participants examined the range of blended engineering disciplines / degrees that are possible given the broad range of Fourth Industrial Revolution technologies. Small groups selected a blended program and then discussed the licensure considerations associated with the selected program.

- What public protection considerations would you have as an engineer working within that emerging discipline?
- What role should licensure and regulatory processes play in ensuring protection of the public interest with respect to the emerging discipline? How do current licensure models work for fulfilling this responsibility?
- What new models for licensure might be considered?

The disciplines selected and the implications for licensure are summarized below.

GROUP 1 – Blended Engineering / Engineering Technology Programs (across typical disciplines)

- All programs should focus on critical thinking.
- Could combine practical application and research.
- Public impact needs to be incorporated in engineering curricula.
- Consider a dissertation evaluation approach to the individual examination that could include an interview of the licensure candidate by a committee of practitioners combined with a fundamentals and/or ethics exam.
- Multidisciplinary board is necessary to assess multidisciplinary candidates.

GROUP 2 – Artificial Intelligence

- Ethics is a major consideration.
- How do we regulate accountability?
- Should software be licensed in addition to licensing individual engineers that are applying the software?
- There needs to be stronger requirements for multi-disciplinary peer reviews as software becomes more complex.

GROUP 3 – Traffic Systems Engineering

- Privacy considerations around consumer's access to data are important.
- Licensure model must address these ethical considerations but testing for ethics is difficult.

GROUP 4 – Mobility Engineering

- Ethical considerations related to the decisions made by AV's are a critical element of licensure, and these are difficult to regulate in the current model.
- Look to the medical profession as a model for licensure- identification of specialty discipline.
- Consider multi-disciplinary peer review.

GROUP 5 – Smart Infrastructure

- Public safety and welfare is the most important consideration.

Provocation

NEW LICENSURE MODELS: INNOVATION VERSUS DISRUPTION

PATTY MAMOLA, P.E.
EXECUTIVE DIRECTOR, NEVADA STATE BOARD OF PROFESSIONAL ENGINEERS AND LAND SURVEYORS

LANCE KINNEY, P.E.
EXECUTIVE DIRECTOR, TEXAS BOARD OF PROFESSIONAL ENGINEERS AND SURVEYORS

In their concluding provocation, Patty Mamola and Lance Kinney reminded participants of the timeless expectations of engineering licensure.

1. The public relies on the competence and ethics of professional engineers to keep them safe.
2. Professional engineers must regard their duty to public health, safety, and welfare as paramount.
3. Regulators protect the public by setting standards and holding practitioners accountable to those standards.
4. Professionals are entitled to be governed by practices that are transparent, objective, impartial, fair, and timely.

In the Fourth Industrial Revolution, society is accepting new technologies without regard to regulation or to ethical concerns. Companies such as Uber and Lyft are examples of this disruption. These technological disruptions put the current model of engineering licensure at risk. Patty and Lance again emphasized that we must think beyond incremental adjustments to our current system of licensure. Licensure in the future needs to consider new approaches.

- ***Most Effective Use of Exams***
- ***Phased Licensing***
- ***Tiered Licensing***
- ***Licensing for Ethics in Addition to Technical Competency***
- ***Licensing of Teams***
- ***Licensing of Projects***

GROUP EXERCISE III – LICENSURE MODELS / INNOVATIONS & DISRUPTIVE TRANSFORMATIONS

In the final group exercise, participants were asked to identify possible elements of a new regulatory system that should be considered by the engineering community and its regulatory ecosystem. Group discussion confirmed the need for major changes in current licensure models with the key drivers of this need including the difficulty of regulating emerging technologies and the blurring of the lines between engineers, developers of technology, and the public. These ideas can provide a framework for a model for licensure that is needed in the Fourth Industrial Revolution.

1. Self-regulation like the Canadian model.
2. National regulation administered in collaboration with State licensing boards.
3. National regulation administered by professional associations.
4. Incorporating elements from other professions such as the medical profession and their emphasis on preventing harm while providing benefits.
5. Capturing life-long learning as an element of licensure.
6. Licensure based on credentials, such as a portfolio demonstrating essential engineering skills.
7. Licensure by multi-disciplinary committees or peer reviews.
8. Examination on ethics only.
9. Licensure requirements for software developers.
10. Broadening the net through licensure of all engineers immediately after graduation.
11. Education of state licensing boards on emerging technologies.
12. Education of the public with respect to evaluating technologies and engineering issues.
13. Recognition that those with means will get licensed and those with life challenges may not place as high of a priority on getting their license.

Conclusion

The role of ECL-USA is to be a catalyst for change, helping the engineering community to reach its highest potential on behalf of society. Accountability to the public is an essential element of fulfilling this mission. Our licensure system is the means of ensuring that accountability, and it must adapt to the technological disruptions of the Fourth Industrial Revolution. Hopefully, the outcomes of Summit 10 will serve as guide to those who are charged with the stewardship of our licensing system.

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Context:

Technology: Artificial intelligence, machine learning, data analysis, the Internet of Things, and other technologies often developed by non-engineers increasingly being utilized in engineering solutions.

Education. Emergence of new engineering disciplines, new engineering technology programs, and blended, multi-disciplinary degrees driven by industry and student demand. "Interdisciplinary education is 'blowing up the silo' that engineers should be educated in only one discipline. Engineering students are increasingly diverse and seeking different ways of thinking and different approaches to solving problems." (Tim Jacobs, Texas A&M)

Legislation: Increasing focus by legislators on reducing barriers to entry and easing the portability of licenses.

Public Perception: Lack of understanding by the public of what engineers do, of the fact that not all engineers need to be licensed, and of the differences between software developers and licensed engineers.

Engineering Practice: Complex, inter-disciplinary, collaborative projects; imperative for more sustainable, resilient designs; increasing stakeholder and public involvement; technologies spanning jurisdictional boundaries, integration of emerging technologies into projects, and engagement in design of and design within systems of systems.

Breadth of Engineering Community: Growing numbers of engineering technologists and non-engineering technologists within the overall population of the engineering community.

Industrial Exemption: The industrial exemption which has been used to shield engineers working in industry from licensure requirements was originally designed to serve the needs of 2nd Industrial Revolution industries (complicated technologies whose risk and liability could be effectively assessed and assigned to industrial corporations or governmental agencies). The emerging technologies of the 4th Industrial Revolution are nested in complex systems involving numerous parties that span multiple regulatory and corporate boundaries, significant and often difficult to assess risks, and highly ambiguous situations where responsibility is hard to assign to a single party.

Mapping a *Transformational* Shift

Internal Combustion Engine

Electricity

Assembly Line

Advanced Chemistry

From...
Today's **Licensure Model** largely conceived and structured to address the technologies of the 2nd Industrial Revolution

1

Micro-Ethics & **Macro-Ethics**
A focus on ethics extending beyond the "micro-ethical" concerns addressed by the traditional licensure model to encompass the responsibility of engineers for the macro-ethical issues presented by emerging technologies and the entire systems impacted by engineering projects

2

Analytical & **Critical Thinking**
Technological challenges of the 4th Industrial Revolution demand not only the traditional analytical and problem-solving abilities, but also mastery of critical thinking and systems thinking skills as well as an enhanced capacity for self-awareness and reflective practice.

3

Single License to
Modular Regulatory Schemes
Adoption of a tiered and/or phased regulatory system that parallels the growth and development of individual practitioners and teams. This could include an early license focused on engineering basics and ethics, followed by tailored licenses and certifications for disciplines / areas of practice.

4

Static / High Inertia to
Agile & Adaptable
Given unprecedented advances in technology, new principles, protocols, rules, and policies are needed to accelerate the positive and inclusive impacts of these technologies, while minimizing or eliminating their negative consequences. Current regulatory institutions, including engineering licensure, are struggling to keep up. There is an urgent need for a more agile approach to licensure that can adapt in real-time to a rapidly changing socio/technological environment and address potential exponential impacts that often accompany emerging technologies.

5

Education / Exam / Experience & **Portfolio / Peer Review**
Shift from the current model which relies on an exam with education and experience requirements to a regulatory system that also includes credentials, such as a portfolio demonstrating essential engineering skills, peer reviews (multi-disciplinary peer reviews) certifying professional competence, values, and mindsets, and/or dissertation evaluation approaches.

6

Disciplinary Body of Knowledge & **Lifelong Learning**
Supplement the current model, which tests for competence with respect to a discipline's technical body of knowledge at a certain point in time, with strong requirements for lifelong learning and mastery of an ever-evolving professional domain (emphasis on emerging technologies and complex socio-technological systems).

7

Single Discipline & **Interdisciplinary**
Combine existing licensure for a single discipline (civil, mechanical, electrical, etc.) with licensure and certifications for interdisciplinary practice (mobility engineering, biomedical engineering, smart city engineering, robotics, de-carbonization engineering, etc.)

8

Individual Practitioner & **Team-Based Practice**
While continuing licensure of individuals develop team-based (project or platform based) licenses that can encompass teams of engineers, engineering technologists, computer programmers, and non-engineers engaged in the creation and development of emerging technologies.

9

State-Based to **Blended Self-Regulation, State, National, & Global**
Move from a licensure model dominated by state regulation to a blended licensure system that combines self-regulation (Canadian model) with state and national (and global) requirements and regulations.

Artificial Intelligence

Cyber-physical Systems

Virtual Reality

3D Modeling

Big Data

Internet of Things

To...
A future **Regulatory System** designed to fit the needs of the present practice of engineering as well as the needs and dynamics of the 4th Industrial Revolution and the Engineering Grand Challenges of the 21st Century.

Expectations for Regulatory Systems:

- The public relies on the competence and ethics of engineers to keep them safe.
- Professional engineers must regard their duty to public health, safety and welfare as paramount.
- Regulators protect the public by setting standards and holding practitioners accountable to those standards.
- Professionals are entitled to be governed by practices that are transparent, objective, impartial, fair, and timely.

Tenets:

1. Foster the role of engineers and the engineering community as stewards of technology and nature on behalf of society.
2. Move beyond only the protection of the public interest to the incorporation of a beneficial mindset.
3. Attract a higher percentage of the engineering community toward formal recognition of professional status.
   - Increased public benefit
   - Enhanced trust
   - Symbol of professional identity. purpose and commitment
4. Improve social equity, diversity, and inclusion. Remove unfair barriers to licensure for disadvantaged members of the engineering community.
5. Increase portability across state, national, and global lines.
6. Drive innovation and continuous learning within the domain of the engineering community.
7. "Broaden the view of the outcomes of engineering which shines the light on changes in processes needed and expands the skills that engineers need." (Mark Abbott, ECL-Canada)