Internet of Things Curriculum Workshop: An Interdisciplinary, Cross-Institutional Effort for Education in an Expanding Field

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Abstract

The ongoing 4th industrial revolution, driven by the Internet of Things (IoT), is having profound impacts on industries of all kinds, especially manufacturers. Further, the increasing ability to collect and analyze large amounts of data has impacts beyond manufacturing. Given the critical role that engineering educators play in supplying the engineering workforce for the nation – and the critical role of our schools in other areas impacted by IoT – development and distribution of state-of-the-art undergraduate curriculum that enhances graduates' knowledge and skills in the IoT space is important. Our preliminary discussions with industry have revealed that the desired "IoT" knowledge, at this point, is supplemental to traditional curricula, not (yet) something that would replace topics seen as core to most engineering programs. However, this frames the challenge of curriculum development in this area: the topics are by nature interdisciplinary and may extend beyond a faculty member's typical comfort zone. Therefore, our institution hosted an Internet of Things Curriculum Workshop in January 2019. The purpose of this workshop was to support faculty members from across our state to work together, to collaboratively develop and share IoT course modules to enhance educational outcomes for engineering and other programs state-wide. This workshop was designed to enable faculty to: (1) learn about the need for curriculum directly from industry collaborators at a round-table discussion; (2) learn about existing IoT curriculum development efforts at sister institutions; (3) begin the collaborative development of new course modules to enhance existing, and potentially new courses in a wide range of engineering and related disciplines. The modules are to be broadly accessible across our state and will serve as a first step toward broader dissemination of IoT-related topics in engineering curricula. This paper will present the planning, organization, and structure of the workshop, including a report of its lessons learned, initial findings and results, with the purpose of enabling other institutions to learn from our experience.

Introduction

The ongoing 4th industrial revolution, driven by the Internet of Things, is having profound impacts on Wisconsin industries of all kinds, especially manufacturers. Further, the increasing ability to collect and analyze large amounts of data has impacts beyond manufacturing. Given the critical role that the University of Wisconsin-Platteville, UW-Milwaukee, UW-Stout, and UW-Madison play in supplying the engineering workforce for the state of Wisconsin – and the critical role of UW System schools in other areas impacted by IoT – development and distribution of state-of-the-art undergraduate curriculum that enhances graduates' knowledge and skills in the IoT space is important.

Preliminary discussions with industry have revealed that the desired "IoT" knowledge, at this point, is supplemental to traditional curricula, not (yet) something that would replace topics seen as core to most engineering programs. However, this frames the challenge of curriculum development in this area: the topics are by nature interdisciplinary and may extend beyond a faculty member's typical comfort zone.

To this end, the Internet of Things (IoT) Curriculum Workshop, co-hosted by UW-Platteville and UW-Milwaukee, was held on Thursday, January 17, 2019. It was funded by the University of Wisconsin System (UW System) and the Wisconsin Economic Development Corporation (WEDC). The workshop featured 65 participants: 20 leaders and engineers from 12 companies, and 45 faculty, staff, and administrators from seven UW System schools. *(See Appendix for details.)*

Table 1. Participants by Institution and Academic Discipline

Ashley Furniture Industries (6)	B&R Industrial Automation (1)
Faith Technologies Inc. (1)	GE Healthcare (1)
Ingersoll Rand/Trane (2)	Kimberly-Clark Corporation (2)
Kohler Company (1)	Rockwell Automation (4)
Microsoft (1)	What's Possible Education (1)

UW-Platteville (21)	UW-Milwaukee (6)	UW-Madison (4)
UW-River Falls (2)	UW-Stevens Point (1)	UW-Stout (5)
UW-Whitewater (2)		

Civil Engineering (2)	Mechanical Engineering (3)	Industrial/Systems Eng. (4)
Physics/Engineering Physics (2)	Information Technology (3)	Computer science (9)
Industrial Studies/Eng. Tech (3)	Math (1)	Business (1)
Educational technology (2)	Industrial design (2)	Operations & management (1)
Communications (1)		

The purpose of this workshop was to support faculty members from across the UW System to collaboratively develop and share IoT-related course modules to enhance educational outcomes for undergraduate students in engineering and related programs state-wide. This workshop supported this goal through the following activities:

- Learn about curriculum content needs directly from industry collaborators;
- Learn about existing IoT curriculum development efforts at sister UW-System institutions;
- Begin the collaborative development of new two-week (nominal) instructional modules to enhance existing courses across a wide range of engineering and related disciplines.

As mentioned above, preliminary discussions with industry revealed that IoT topics were largely seen as supplemental to existing programs. Some knowledge was identified as cross-disciplinary; for example, sensors content could be augmented with networking topics that are typically in computer science. Other knowledge was an extension or a special application of existing topics; for example, in computer science, using cloud services to create the backend for a system that can receive and respond to requests from connected devices. Both types of supplemental knowledge can be readily introduced by building on existing courses and "extending" course topics when they naturally connect with the new IoT-related material. This pedagogical approach can alleviate some of the challenges of incorporating new, interdisciplinary content into the curriculum. For one, fully cross-disciplinary courses can have daunting logistics, including coordination and scheduling across different departments, and meeting the needs of students from multiple disciplines. New courses also present challenges of teaching workload, fitting into the overall curriculum, and presenting a larger task for the instructor when course-planning a semester's worth of new material.

Therefore, the "module" approach was taken to facilitate the inclusion of IoT content as quickly and as broadly as possible, and to better accommodate cross-disciplinary collaboration. This approach enables updating of the existing curriculum, while offering the potential for future new courses that could be created by combining multiple instructional modules [1]. (The idea of combining modules into a single course is inspired in part by the Connected Enterprise Concepts course developed at UW-Milwaukee with industrial partner Rockwell Automation, Inc. This course, for senior undergraduate and graduate students, provides a survey of "Connected Enterprise" topics such as security, analytics, and business. One potential outcome of these instructional modules is that an undergraduate "Introduction to IoT" course could result.)

Conceptually, the module approach is compatible with the micro-credentialing trend, in which "badges" are granted for demonstrated competency in focused areas [2]. The modules here, however, build upon advanced knowledge that is part of a four-year degree; so, we anticipate that the most immediate application would be for the four-year student population. In the future, one might imagine successful modules being repurposed as part of continuing education in IoT for practicing engineers. This would require modifications to the modules' structure, delivery and assessment, which are beyond the scope of the current effort. For now, with the goal of rapid development and implementation, the focus is on existing courses with traditional undergraduates.

Teams will continue development after the workshop, facilitated by the UW System learning management system, Canvas. This would make the modules broadly accessible across the UW System and serve as a first step toward broader dissemination of IoT-related topics in engineering curriculum.

It should be noted that the term "IoT" as used here refers to the broader application of "smart," connected systems. The topics under development also include aspects of areas such as "IIoT" (industrial internet of things), Industry 4.0, and Connected Enterprise. Much of this is sensibly connected to manufacturing, given its large impact in Wisconsin's economy: 16% of its workforce – nearly twice the national average – is in manufacturing [3]. However, IoT applications also extend into such areas as traffic, infrastructure, agriculture, and consumer products; the workshop was intended to also offer a "home" for these interest areas.

Workshop planning and structure

The author, a senior faculty member with course-related interests in IoT who was already heading an *ad hoc* "IoT Education" committee in the college, was asked by the Dean to direct the workshop. The initial plan for the workshop was to host a small number of industry representatives, perhaps five, in a half-day roundtable discussion of IoT-related curriculum needs; it was expected that perhaps 15 faculty from multiple institutions would take part. However, when the workshop was announced, we received a large amount of interest from our sister institutions. Additionally, our industry contacts – initially contacts from advisory boards for the two co-hosts – responded very strongly positively and several companies sent more than one engineer. Further, as word spread, other regional companies asked to join the workshop. We decided to err on the side of gathering as many viewpoints as possible and accepted all who were willing to participate; very quickly, "five plus fifteen" participants grew into "twenty plus forty-five."

With these large numbers the original roundtable idea was deemed infeasible. Therefore, we decided to split the industry participants into smaller break-out groups that would subsequently report back to the full group. The purpose was to better ensure that each individual could be heard. Continuing in this mindset of "maximum information extraction," we decided further to separate out the faculty and have them meet in parallel with the industry session; this would not only facilitate collaboration across the campuses but would help ensure that we would first listen to what the industry participants had to say.

It should be noted that several university participants – i.e. deans, department chairs, administrators – were primarily interested from the perspective of strategic planning, not curriculum development. Therefore, they observed the industry break-out session instead of participating in the faculty session.

Overview of the day

After a welcome from Dr. Molly Gribb, UW-Platteville Dean of the College of Engineering, Mathematics and Science, next Prof. Ethan Munson, Associate Dean for Academic Affairs at UW-Milwaukee presented an overview of the Connected Systems Institute. Prof. Hal Evensen (UW-Platteville, workshop director) then gave an overview of the workshop and shared the goals of the day: identifying IoT-related Knowledge, Skills, and Abilities and beginning to translate these into curriculum modules that for a broad range of students. Finally, he shared the Educational Outcomes expected of all accredited engineering programs (per ABET [4]), as a point of reference: participants were encouraged to also think beyond technical skill requirements and to consider other skills that are part of science, technology, engineering & mathematics (STEM) curricula such as teamwork, consideration of ethical/societal issues, and more.

At this point, the industry participants and academic participants were split into break-out sessions to focus on delineating their needs, before coming back together as a large group before lunch.

Industry Break-out: Summary

The industry "room" brainstormed and focused on shared key "Abilities," "Skills" and "Knowledge."

- "Abilities" refers to the power or capacity to perform an activity or task. For example, having the ability to use a variety of laboratory instruments [5], or the ability to plan and organize.
- "Skills" are the capabilities or proficiencies developed through training or hands-on experience. Skills are the practical application of theoretical knowledge. Someone can

take a course on investing in financial futures, and therefore has knowledge of it. But getting experience in trading these instruments adds skills [6].
- "Knowledge" statements refer to an organized body of information usually of a factual or procedural nature which, if applied, makes adequate performance on the job possible; a body of information applied directly to the performance of a function [7].

Ideas were captured using flip charts that were later shared with faculty. The Appendix shows *all* of the captured feedback, unedited but reorganized to highlight eight themes that emerged. Though there is certainly some overlap among these eight themes, this grouping serves to show the several broad consensuses. It is worth noting that in general, these themes were seen as needed of engineers from *most if not all* disciplines.

1. Business. Engineers are becoming much more directly involved in the business aspects of their work. This requires them to be more aware of the "big picture" of the company, or more precisely, the "business picture." As a result, there is a need for increased knowledge of business-related topics as well as a business perspective. Further, there is an increased need to be able to communicate and navigate the "business culture and environment" of the company. This topical area had the most bullet points from the discussions.
2. Engineering skills. There was an extensive list of desired skills or abilities. The most prominent were:
    a. Hands-on, "technician-like" skills including integration, testing, and knowing the limits of hardware.
    b. Communication skills, especially documentation and producing written procedures. Interpersonal communication and the ability to present effectively to different audiences were also highlighted.
    c. Programming was unanimously identified by the groups as a key ability. This includes traditional software engineering skills as well as ladder logic.
    d. Cybersecurity issues were also identified – from internal security, to network security, to consumer security. The needs of cybersecurity also include penetration testing (i.e. hacking) and risk assessment.
    e. Supply chain knowledge also was frequently called out.
3. Project management skills, the design process, and innovation were also frequently identified (and with much overlap):
    a. Project management methods and skills included Scrum (for projects) and Agile (for software), as well as DevOps.[a] Budgeting, scheduling, outsourcing and subcontracting were also identified.
    b. The Design process remains as important as ever. The need to develop and prioritize specifications was seen as very important, as was the need to understand and apply standards; the latter was identified as a relative weakness among engineers at present.
    c. The need for innovation was called out several times, as one might expect when considering disruptive new technologies.

[a] "*DevOps is the practice of operations and development engineers participating together in the entire service lifecycle, from design through the development process to production support*." https://theagileadmin.com/what-is-devops/

4. Cross-disciplinary knowledge and teaming was another strong theme. This included:
    a. Knowledge and mindset: not only knowing what other disciplines do, but also valuing and fostering interdisciplinarity.
    b. The ability to work across domain knowledge – cross-collaboration – was highlighted. This extends beyond technical disciplines to include interactions with Marketing, with other industries, and (as discussed above) with Business.
    c. Teamwork, by extension, was also named as significant – the enabling skill for cross-collaboration. However, the need goes beyond team mechanics end extends to *building appropriate teams* and getting the right people involved, from across disciplines.
    d. Significantly, this area included direct suggestions regarding engineering education:
        i. teaching students the connections across disciplines;
        ii. developing more multidisciplinary courses;
        iii. creating cross-disciplinary capstone courses.
5. Data was a prominent topic. This included knowing the basics of data science and also the data processing experience: collection; cleansing and manipulation; and visualization. The needs of "big data" also overlapped into security concerns as well as being able to apply machine learning and artificial intelligence tools.
6. With the sweeping transformation that IoT technologies promise, another very strong recommendation was the need for continuous, lifelong learning and continuing education. Engineers need to be able to rely on their research, and to become comfortable with "not knowing" (and with subsequently learning and trying new things). Additionally, "change" was a key concept: the ability to innovate change, manage change, and adapt to change were called out repeatedly.
7. The Systems approach was also highlighted: thinking holistically; understanding the systems approach and systems thinking; and using systems to predict outcomes. This makes sense as IoT technologies can be used to link together many smaller systems through their data.
8. Networking and communication skills were also identified; engineers need to be familiar with communication protocols and have experience with different network setups.

Finally, the industry participants made additional recommendations regarding higher education. They highlighted the need for more internships for undergraduates and "up-skilling" for those at all levels of education. They also reiterated the need for interdisciplinary education. They further extended recommendations to the secondary schools for "authentic" industrial technology and high school counselor education.

Faculty break-out: summary

Concurrently, the faculty and staff participants went through a series of exercises. First, the institutions shared their ongoing efforts and capabilities; this was meant to introduce everyone to their fellow System schools and to foster collaboration. Next, they shared the challenges they face in trying to extend their curricula to include IoT topics; finally, they developed key questions or issues that they hoped address with the industry participants. These were shared with the industry group, and at the same time they were presented an overview of the industry participants' collection of desired Knowledge, Skills, and Abilities (above, and Appendix).

The list of "issues and questions" from the university participants is attached in the Appendix. The faculty feedback presented there has been condensed (in part since the author was part of that discussion). Perhaps unsurprisingly, resources were identified as a key need – if not *the* key need. This ranged from the need for easier access to software licenses – perhaps System-wide licenses? – to accessing resources via sharing with other institutions and companies. The issue of on-site training for faculty and staff was also raised. Also, the recognition that equipment and software must be maintained and updated leads to the need for establishing continuing partnerships and collaborations.

The main technical questions were, simply, what does industry want students to know – both in general and specifically? What "knowledge kernels" (i.e., key topics) would apply to all students? What deeper knowledge would be needed of different disciplines? (It is assumed that different disciplines would subsequently delve into particular "kernels" with depth appropriate to their field of study.) It is of great interest to elucidate this desired common set of knowledge and awareness.

The faculty also expressed a desire for assistance in identifying course material and the relevant standards in use. This includes questions such as what technology is being used; what are the protocols; what is the standardization? Further, the question was raised regarding the choice between hands-on and simulated laboratory experiences – both can be valuable but finding an appropriate mix can be a challenge.

The issue of "vendor-neutral instruction" also arose. Students will be working in a range of industries, with a variety of implemented technologies – often even within the same company. (Additionally, in-depth learning occurs when students work with multiple different solutions.) Being able to teach effectively in this vendor-neutral way would require knowledge on interoperability – this is likely done in the manufacturing setting now, with multiple vendors' technologies in operation at a single site. How can we extend this to the academic setting?

The university participants also discussed the need to work closely with industry to stay abreast of the "next big thing." In other words, what problems are being solved by industry today vs. the problems they will be solving tomorrow; what technology is in development? Insight into this will help ensure that curricula stay relevant.

In the area of direct support for student learning, participants expressed interest in facilitating continuing internships for students (which was also raised by the industry participants), as well as creating opportunities for field trips and guest speakers.

Participants also identified constraints and challenges they face when implementing IoT concepts into their curricula. These included:

- Time for both learning and staying current, as well as preparation of materials;
- Credit hour constraints: our degree programs are expected to stay near 120 credit hours overall, meaning new material will displace something. For example, while "business

topics" are very much in demand, it is not obvious how to integrate this into existing undergraduate engineering curricula. Finally, as new courses are developed, unintended impacts on potential transfer credits across institutions may occur.

- Students will need to be exposed to concepts that are outside of the traditional curriculum. This can lead to resistance to these new ideas – i.e., "I went into X so I wouldn't need to learn Y." Additionally, cross-disciplinary courses also pose challenges because any classroom will have an especially wide range of backgrounds and prior knowledge.
- Faculty who tend to stay within the "silos" of their disciplines were also seen as a challenge to collaboration, and also to fitting these new ideas into the curriculum.

Finally, an idea emerged from this discussion that may help to address all of these questions: a **state-wide topical area advisory board**. This could be similar to the group that just convened, enabling industry to touch multiple campuses at once and giving the campuses an avenue by which they can collaborate with each other and with regional businesses. The results of this workshop can inform future efforts in this area.

Afternoon session: module identification and development

The purpose of the afternoon session, broadly, was (1) to identify topics for IoT-related educational modules based on the morning discussions, and (2) to form teams to develop these educational modules. These modules would consist of roughly "two weeks" of material in a three-credit course: six classroom hours, instructor materials, assessments, etc. The purpose behind this two-week framework was to present a low barrier to development and implementation.

To this point in the workshop, the industry and faculty representatives had only minimal direct interaction. Now, though, all participants worked together to identify topical areas for educational modules. In an active session, we listed and grouped topical areas that were ripe for inclusion into "modules."

The module topics, which were not prioritized, are given below:

- Programming languages & techniques
- Networking / real-time solutions
- Networking / non-real-time solutions
- Networking / security & cyber-security
- Networking / protocols (TCP/IP etc.), OSI layers, real-time extensions
- Intro to IoT for Dummies: sensing, networking options
- Digital twin / model creation
- Data:
    - Data acquisition
    - Data management
    - Data analysis / applied statistics
    - Data visualization
    - Data governance
- Microelectronics for IoT edge devices

    - Smart sensors
    - Smart devices
    - i.e. using Arduino etc.
- Systems thinking
- Human aspects:
    - Ethics
    - Societal impact
    - Privacy
    - Safety
    - User Experience / User Interface
- Artificial intelligence & machine learning
    - Understanding algorithms & language
    - "Between magic and math"
- Design for debug
    - Troubleshooting
    - Sustainability
- Updatability / life cycle
- Standards and interoperability
- Fundamentals of Business applications for IoT, Engineers & case studies
- Programming
    - Microdevices
    - "Back end:" to cloud, network
- IT/OT[b] integration
- New consumer product concepts (including standards)
- MES & ERP[c] integration (business aspects)

Next steps: module development

In the final part of the workshop, faculty and industry participants selected the modules that they would develop for incorporation into a course in the near-term (roughly Spring 2020 or sooner). The module topics given above are rather broad; further definition and refinement depends on the needs of the different majors and the particular implementation. Thus, the faculty teams narrowed the focus as they developed their modules. For example, one module is titled "IoT Networking Protocols," which will be incorporated into a 4000-level Engineering Physics course in Sensors. In this module, students will learn the fundamentals of networks and the Open Systems Interconnection (OSI) model and create a small network of sensors. It is likely that this module could be adapted, for example, into any similar course for engineering majors who have basic knowledge of sensors and wish to extend into networking topics.

Teams are collaborating across the UW System through the Canvas learning environment, which has recently been implemented at all campuses. Canvas "courses" have been created for each of the IoT modules, and "instructors" – those with read/write privileges – have been assigned. These instructors come from multiple campuses, with some from industry also participating.

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[b] IT/OT = Information Technology / Operational Technology

[c] MES = Manufacturing Execution System; ERP = Enterprise Resource Planning

Using Canvas allows instructors to readily share and develop materials, and it will also facilitate dissemination after the modules are completed. The Canvas course modules in progress thus far are listed below.

IoT Networking Protocols ♦ UW-Platteville ♦ UW-Madison ♦ UW-Milwaukee ♦ Ingersoll-Rand/Trane ♦ B&R Industrial Automation	**IoT Backend Programming** ♦ UW-Platteville ♦ UW-River Falls ♦ UW-Milwaukee
Social, Economic and Ethical Issues of IoT ♦ UW-Whitewater ♦ UW-Milwaukee	**New Product Concepts / Economic Issues & Impacts** ♦ UW-Stout ♦ UW-Milwaukee
Intro Sensors A: Types & Applications ♦ UW-Stevens Point ♦ UW-Whitewater ♦ UW-Platteville ♦ UW-River Falls ♦ UW-Stout ♦ UW-Milwaukee	**Intro Sensors B: Trade-offs/Selection** ♦ UW-Stevens Point ♦ UW-Whitewater ♦ UW-Platteville ♦ UW-River Falls ♦ UW-Stout
Data 1: Data Acquisition ♦ UW-Platteville ♦ UW-Stout ♦ UW-Milwaukee ♦ Kimberly-Clark Corporation ♦ GE Healthcare	**Data 2: Big Data Analytics** ♦ UW-Platteville ♦ UW-Stout ♦ UW-Milwaukee ♦ Kimberly-Clark Corporation ♦ GE Healthcare
Data 3: Data Management ♦ UW-Platteville ♦ UW-Stout ♦ UW-Milwaukee ♦ Kimberly-Clark Corporation ♦ GE Healthcare	**Data 4: Visualization** ♦ UW-Platteville ♦ UW-Stout ♦ UW-Milwaukee ♦ Kimberly-Clark Corporation ♦ GE Healthcare
IoT Systems / Connected Systems ♦ UW-Platteville ♦ UW-Milwaukee	**Cybersecurity** ♦ UW-Milwaukee

The modules are to be completed by June 1, 2019. At this time, they will be shared with interested industry participants for review, to be completed by July 1. Faculty participants are then eligible to receive a stipend of at least $1,000 per module, commensurate with their overall level of participation.

The UW-Platteville Center for Distance Learning will use the peer-reviewed module content to develop online modules that can be used in online, hybrid, or in-person courses; these will be available for use in Fall 2019 and beyond. The curriculum modules will be previewed at the

Wisconsin Science and Technology Symposium (WSTS, July 22-23, 2019; organized by the WiSys Technology Foundation[d]).

Feedback, future and conclusions

A post-workshop survey was distributed to participants, in order to gauge their response to the workshop, its perceived value, and suggestions for future implementations. Eleven participants responded; the results of the survey and additional, informal feedback are discussed here.

The workshop was well-received in general. The most beneficial aspects of the workshop were identified as identifying the needs of industry (80%) and networking with industry people (80%). Using a five-point Likert-type scale, a question on overall quality and usefulness of the workshop scored 3.6 out of five; a question on whether we should re-convene the workshop next year scored 3.8.

The respondents identified several areas for improvement, all related to the workshop structure. The greatest consensus was that more and better-quality interaction was needed between industry and faculty, including an improved means to facilitate the morning discussions and capture the discussion topics. It was also suggested that some pre-workshop work, done virtually, could have helped in this regard. This was certainly apparent as the workshop progressed; there were many needs identified by industry – too many to be fully absorbed in the allotted time – and many contributing points of view. In one sense, in response to its rapid growth, the workshop was set up as a shortened "DACUM" process, which typically takes much more time than a half-day [8]. On the positive side, the workshop could be viewed as a valuable first step to appreciate the scope of the needs of industry, which will help to streamline future efforts.

Another issue raised had to do with tension between the two different types of curricular need that arose. One is for *cross-discipline* content, which may be new for one major but considered "introductory" for another – for example, incorporating business topics into engineering curricula. The other is for *extended* content, which is relevant to IoT but mostly so for a single major – for example, the details of backend programming for connected devices, for computer science majors. The workshop was created with the former in mind, so some participants felt that the resulting module areas were too "shallow," or not inclusive enough of those with expertise. This was probably exacerbated by the fact that in the afternoon session, a faculty member naturally had to choose a single module to begin work on, even if they had expertise to offer to other modules. A positive interpretation is that having uncovered the wide scope of the curricular need, future efforts can be adjusted to accommodate them.

Overall, it appears that the workshop was well-received and seen as a great opportunity for both industry and university participants. Looking through just the topical ideas captured and discussed above, however, it is clear that more work could be done. For one, several points could bear further clarification, and in particular a more detailed discussion of the particular

[d] WiSYs is the official designated technology transfer office for the UW System Comprehensive Campuses. WiSys advances scientific research throughout the state by patenting technologies developed out of the universities and licensing these inventions.

knowledge needs would be fruitful. (It is expected that some of these discussions will occur during the creation of the instructional modules.)

A criticism of the Knowledge-Skills-Abilities model is that the three terms can have a lot of overlap (or in some cases, seem to be interchangeable). The results here seem to bear this out: there was significant overlap in what was reported, indicating that this distinction may be hard to implement in a workshop setting. In the future, a DACUM-type process – which uses the definitions of Duties and Tasks associated with a job – may prove easier to follow and build upon [9].

Several ideas were raised independently by both industry and university groups that bear further discussion and exploration. These include extended internship opportunities for students, faculty training externships, and other interactions such as field trips and guest speakers. These, plus the general theme of the campuses wanting to better stay abreast of ongoing developments in industry, suggest that a second meeting, workshop, or topical advisory board is warranted. We expect that a second gathering, re-structured based on the lessons learned from this event, would be welcomed and even more productive. We plan to have discussions on the next iteration when participants gather to present their modules at the Wisconsin Science and Technology Symposium in summer 2019.

Appendix I – Industry responses

"Big Picture" sheet:

- Digital technology culture & talent: "digital warriors"

  AND

- Engineering & technology, integration of systems, business risk/analysis cost/benefit

Business aspects that are not typically part of engineering education

Being aware and involved with the workings of the business

- Knowledge of beginning-to-end business processes
- Understand business
- "Business for engineers:" return-on-investment (ROI), basics
- Business solution architecture (1st)
  - Technical architecture for solution (2nd)
    - Commercial understanding of risk (3rd)
- Define business objectives
- Identify business outcomes
- Identify & develop a business case
- Business planning
- Industrial-scale understandings
- Big picture of manufacturing business
- Throughput
- Understanding of various enterprise functions
- Build closer relationships with consumers
  - Leverage social media tools
- OT, IoT, & business – integrating functions
- From information technology (IT) to business intelligence (BI)

The Business Culture / Communication within the business

- Culture: be able to talk to business and translate into technology
- Organizational behavior
- Get "top down traction"
- Technology & engineering & business shared language (& cross collaboration)
- Cultural mapping: geography & functional translating level in organization
- Negotiation
- Be familiar with work environments and how systems work

General Engineering expectations/desires

Hands-on

- Engineers with technician skills
- Process control
- Integration
- Legacy integration
- Be familiar with tools
- "Lab" skills – hands-on

- Hands-on practice – hackathon
- Hardware & data limitations
- Testing

Communication

- More interpersonal communication skills
- Importance of documentation
- Write procedures / processes that others can understand
- Present to different audiences

Programming & computer

- Engineers need IT/software engineering
- Programming (*unanimous; all groups*)
    - Design requirements
    - Robotics
- Ladder software development
- Software code review & tools
- Artificial intelligence

Cyber Security

- Internal IoT
- Outside network
- Consumer
- Penetration testing (hackers)
- Incidence response
- Architecture & risk assessment

Other skills/topics

- Analytical skills
- See manufacturing & supply chain as "sexy"
- Supply chain systems
- Robots
- Apply creativity to machine learning & connectivity
- Use core science to "solve IoT"
- Integrate practice with their education (i.e. via experience)
- What happens after you produce something
- Understanding product life cycles
- Quality
- Human factors
- Modeling → operational models (assets, systems)
- Natural language queries

Ethics/critical thinking

- Critical thinking
- Identify stakeholders
- Ethics
- Understand legal & ethical issues

Project management, Design process, & Innovation

<u>*Project management*</u>

- Project management (*given twice*)
- Agile
- Agile process – iterative
- Scrum "*Agile is a general philosophy regarding software production, Scrum is an implementation of that philosophy pertaining specifically to project management*."
- Dev-ops practice: "*DevOps is the practice of operations and development engineers participating together in the entire service lifecycle, from design through the development process to production support*."
- Design management, manage a process
- Schedules
- Budgets
- Working with outsourcing
- Subcontracting

<u>*Design process*</u>

- View technology as enabling
  - Design a system/application to come up with the answer
- Solution-based design
  - Beginning with why: what parameters matter
- Design <u>thinking</u> (empathy)
- Specification & prioritization process
- Specification development – requirements analysis
- Standards
- Standards & safety across industries (generally missing for engineers
- "9 steps", "six sigma" applied

<u>*Innovation*</u>

- Intellectual property sensitivity
- Innovation: multiple solutions & prioritize
- Be innovative

Data-related

- Knowledge of data science
- Understand data, broadly
- The data processing experience:
  - Collection
  - Cleansing
  - Visualization
- Manipulate data
- Methods around data manipulation
- Big data analysis
- Machine learning algorithms
- Artificial intelligence
- Visualization of data
- Data constructs

- Bring in the right data & knowing how to translate it
- Governance / security contexts
- Data & machine integration

Interdisciplinary/cross-collaboration/teaming

Knowledge/Mindset

- Interdisciplinary mindset
- Foster interdisciplinarity
- Know what disciplines do

Collaboration

- Cross-collaboration
- Work across functional groups / across domain knowledge / interdisciplinary / cross-discipline
- Marketing interactions
- Cross-industry communication

Teaming

- Teamwork across campus
- Have a team approach
    - Team mechanics
- Building appropriate teams, getting right people at the table

Education recommendations

- Start teaching students connections across disciplines & industry
- Cross-disciplinary capstones
- Multidisciplinary courses
- Data scientists need some engineering
- Engineering for Business (majors)

Lifelong learning & adaptation

- Continuously learn
    - Build upon previous learning
- Continuous, life-long learning
- Continuing education – applied
- Information/library science: relying on research
- Appreciation & dedication to improve analytical skills
- Be comfortable with ambiguity
- Ask questions
- Technology landscaping (try stuff)
- Change management
- Adapting to change
- Deal with culture change
- Innovation culture
- Willing to take risk
- Failure is not bad: broad, different outcomes may occur

Systems approach

- Understand the Systems approach
- Systems thinking
- Use systems thinking to predict outcomes
- How do humans collect information / interact with systems
- Think holistically (paradigm shift)
- Linking systems: maintenance – manufacturing
- Understand processes

Networking/communications

- Communication protocols
- EE: networks
- Experience with different network setups
- IoT stack

Undergraduate education-related

- More internships
- Upskilling/new skills at different levels
- "Overview" education needed, *plus*
- Separate education
    - Interdisciplinary
    - Business
    - Engineering

High-school-education-related

- Authentic industrial technology at the high school level
- High school counselor education

Appendix II – Faculty/staff summary

Issues, and Questions for Industry related to IoT Education
(bold items identified as Questions for Industry)

- Resources: there is a desire for industrial support and collaboration
  - Support for acquisition of software and materials and equipment
    - **Are System-wide site licenses feasible?**
    - Sharing of shareable resources may be one way. **What can be shared with campuses?**
  - Funding and resources for software maintenance and equipment updates
    - **How can we establish continuing partnerships/collaborations?**
  - **On-site training for faculty and faculty support – how can this be done?**
- Technical content: What does industry want students to know, both in general, and specifically?
  - **Can industry help to identify "knowledge kernels" and relevant skills?** I.e., what information, ideas, and skills are key across "all" relevant disciplines?
    - *There is the expectation that different academic disciplines would go into varying depth for each of these "kernels."*
    - We need to convey the basics of Systems Engineering as related to IoT – what are these, and how?
  - It is challenging to identify course material and standards to adhere to. We need to give our students hands-on experience with the right tools.
    - **What technology is being used?**
    - **What is the standardization?**
    - **What protocols are used?**
    - **What types of laboratory experiences are acceptable to industry: hands-on, simulated (and how to decide)?**
  - There is a desire for "vendor neutral instruction," which utilizes common standards and is not overly-focused on a single vendor's products… but it is not clear how to go about this.
    - **How do we work with industry in a vendor-neutral way?**
  - Will there be something even more disruptive coming on the heels of IoT? If so , how do we maintain relevance – what "pieces" will have the longest relevance?
    - **What problems is industry solving today vs. tomorrow?**
    - **What technology is in development?**
  - **What are some new areas for ethical concerns/issues (arising with IoT)?**
  - **A "topical area advisory board" could be very helpful.**

- Student support and extended learning opportunities
  - **How can we facilitate continuing internships for students?**
  - **How can we create opportunities for field trips and guest speakers?**

Other Issues from Academia

- Constraints and challenges reported by UW System faculty & staff
  - Time constraints on the part of faculty & staff
    - Learning and staying current

        - Preparing materials
    - Academic/credit hour constraints
        - Stay within the nominal "120 credits" while incorporating new material.
        - ABET outcomes do not directly include IoT
        - Transfer of credits between branch campuses is a challenge in a new area
    - Student issues
        - Teach to students beyond engineering (or with varying backgrounds)
        - Students can resist change, incorporation of new "IoT concepts."
    - We (faculty/staff) tend to stay in our "silos" – we need to bring together disciplines for collaboration.
- Other areas of academic interest related to IoT
    - Understanding and conveying the effect of IoT on product development:
        - What is the effect of "IoT" on human interactions (with products, with companies, with others)?
        - How has liability for safety and security changed?

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