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Considering Professional Diversity as a Factor in a Consensus Building Method for Expert Crowdsourcing of Curriculum Topics

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Abstract

State of the art curriculum development efforts today are generally undertaken by solely faculty members of the program. However, in our previous work [anonymized citation], we showed how expert crowdsourcing combined with the application of a consensus building method can be used to perform curriculum development asynchronously with a larger group of experts beyond a program's faculty. The consensus building method included two operations by the expert crowd: (1) validating the existing list of curriculum topics and their subtopics; and (2) suggesting additional topics and subtopics to be added to the current curriculum. We will show results yielded by a finalized experiment utilizing consensus building method against a graduate technology management course's curriculum development.

We will then detail how this research effort incorporated a professional diversity factor into the consensus building method when performing expert crowdsourcing. Professional diversity is important because when building consensus among the experts, we also want to ensure there are enough representatives from various relevant categories of professionals. To calculate professional diversity, we propose a five-step process: (1) Identify the relevant factors, (2) Identify the interactions between factors and relevant categories to consider, (3) Identify the relevance of the identified categories, (4) Identify the ideal recruitment needs, and (5) Compute a global professional diversity measure based on current recruitment.

While this paper is a work in progress, the experiment currently running to test the professional diversity factor will be completed by the end of February 2024 – so the results, analysis, and discussions will be available for the final paper submissions.

Introduction

This research is part of an ongoing series of experiments focused on improving the curriculum development process beyond the typical faculty-focused committee approach to develop course curriculum. The state-of-the-art approach for curriculum development today is to form a committee comprised of two to five faculty members with the occasional industry participant [1]. While this has worked for decades, this approach has challenges in producing curriculum that is relevant for the industry due to the committee's limitations of logistical constraints [2], [3], [4], idea generation potential [5], consensus achievement [5], [6], [7], and professional diversity [4]. Ensuring the curriculum is relevant to the industry is important because graduates and employers are depending on educational institutions to supply a competent and effective workforce consistently. This is especially true in the cyber security and technology-focused industries where a skills and workforce shortage exist, which negatively impacts the ability for organizations to properly protect and respond to the changing cyber environment.

So, in order to develop curriculum that is relevant to the industry, the researchers looked to the crowdsourcing of domain experts to extend the curriculum committee's/owner's pool of topics. Crowdsourcing is the process of gathering answers, opinions, and ideas (called input) from a wide range and large number of different people (the crowd) [8]. And in [9], it was shown that crowdsourcing experts generated more objective inputs from the crowd than when compared to crowdsourcing a non-expert crowd. So, it is no surprised that there have been numerous experiments focused on using crowdsourcing to develop or update courses. While some have used graduating students [2], [7], [10] or online resources [2], [11] to crowdsource, many have used industry professional (experts) for their crowdsourcing efforts [3], [6], [12], [13]. Notably, Nakayama's experiment [6] crowdsourced a small group of five faculty members and industry professionals to update its engineering safety curriculum. Another large-scale experiment [14] had over 200 crowd experts (including faculty, fellows, practitioners, and leaders) to update its medical curriculum.

While collecting inputs from a group of domain experts is important, aligning and integrating their opinions is a difficult problem in knowledge acquisition, being time consuming to achieve consensus between the various inputs from the expert crowd. Group decision-making (or consensus building) is when several individuals are involved in providing input with the goal of solving a common problem or determining a unified decision [15]. Usually, a scoring method or process is used to achieve consensus of what topics to include in the curriculum [4], [10]. For example, [16] performed an experiment to achieve consensus for a medical curriculum with a sizable group of 32 experts where consensus achievement was done through the Delphi methodology. Elliot, Rohlman, & Parish [2] built consensus based on scoring the learner's likability or perceived learning. Slavcev, Waite, & Jennings [13] built consensus by aggregating scores to determine mandatory and optional topics in a curriculum. Jarchow et. al. [17] utilized a four-point scale to score faculty questionnaire inputs for consensus building. Satterfield et. al. [14] built consensus through aggregating their crowd's 1-5 Likert scale inputs. Finally, Nakayama [6] built consensus using a matrix approach to rank and weigh the different competencies in the curriculum.

Since all these previous efforts have relied on manual aggregations, the researchers in this experiment will seek to achieve consensus in a more automatic process through the consensus building function [18] implemented through the dynamic crowdsourcing platform [19]. Consensus building algorithms can be defined as a GDM process where a group of individuals (e.g., domain experts) provide their inputs to support a decision or course of action, and an agreement on a single value, data point, or path forward is determined [20].

In [21], we utilized the Curriculum Development using Crowdsourcing Framework (CDC-F) to run a manual expert crowdsourcing experiment. The experiment started with a baseline curriculum developed by the course's curriculum owner, which consisted of 10 topics and 37 subtopics. The experiment involved 19 domain experts participating in the effort for two iterations. The effort resulted in the confirmation of nine of the 10 topics and all 37 subtopics – "confirmation" meaning the experts agreed these topics and subtopics are necessary and important for the curriculum's industry relevance. The remaining unconfirmed topic was merged with another confirmed topic as a subtopic. Moreover, the effort yielded an entirely new topic to be added, with three new associated subtopics into a graduate course's curriculum. It was noted in the publication that this manual process of aggregating the expert crowdsourcing input was both time and labor intensive – especially the sorting through of over 150 different suggestions (renaming of topics/subtopics and recommendations of new topics/subtopics) from the 19 experts within the two crowdsourcing rounds.

This led to a follow-on experiment [18] where we developed a Consensus Building Function to provide a more automated process of confirmation, rejection, and suggestion processing for topics and subtopics. The consensus building function was implemented on an existing Argupedia dynamic crowdsourcing tool [19] that the expert crowd can interact with asynchronously. In round one of the experiment, 15 expert participants provided 996 different data points when confirming, rejecting, revising (alternative name suggestions per topics/subtopic), and suggesting new topics/subtopics when given the baseline curriculum (description of the course in Appendix A). This resulted in all eight of the topics being confirmed with high confidence, 42 of the 44 subtopics being confirmed with high confidence, and 2 of the 44 subtopics being confirmed with low confidence. 40 new subtopics were also suggested by the expert crowd through Argupedia resulting in 6 being accepted with high confidence, 2 being accepted with low confidence, and the others not yet receiving the minimum number of analysis from the crowd (which will be continued in round 2). However, the described experiment completed just one round of crowdsourcing – so the results were preliminary and a follow-up was promised. In the next section of this paper we will present the final results of the experiment containing both rounds of crowdsourcing. It should also be noted that the baseline curriculum's (Appendix B) development was explained in-depth within this publication [18], along with how an academic committee's curriculum (Appendix C) was developed using the initial baseline curriculum.

Design of Experiment: Concluding the Consensus Building Function

In round two of the experiment, the design and process was the same as in [18] including the consensus building function and its variables, with one exception – the researchers introduced the Name Analysis feature into the crowdsourcing process. A summary overview of the dynamic expert crowdsourcing process with the name analysis feature is as follows:

1. Expert logs into the Dynamic Crowdsourcing Application [19].
2. Expert is presented with Topics and has the options to confirm, reject, postpone, or rename (e.g., for better phrasing or specificity) as they desire based on their expert opinion whether the topic is important/relevant to the course's curriculum and industry.
3. For Topics confirmed by the Expert, its Subtopics are then presented for confirmation, rejection, postponement, or renaming – for the same reason as in step two above. For topics rejected or postponed, the expert will not move forward with the respective topics' subtopics or name analysis.
4. When a topic or subtopic is confirmed or renamed, the expert also has the opportunity to perform Name Analysis on the different proposed alternate names per topic/subtopic that have been suggested by other experts. This involves confirming or rejecting each of the proposed alternative names. The experts can confirm and reject as many of the proposed alternative names as desired (e.g., if there are 6 proposed alternative names for a subtopic, the expert can confirm 2 and reject 4).
5. Experts are able to suggest new subtopics as well. If this is done, experts participating after the suggestions will have the opportunity to perform steps 3 and 4 on the new suggested subtopic, building the crowd consensus for such subtopics.
6. This process is repeated until the expert completes the confirmation, rejection, or postponement of all topics and subtopics; as well as the name analyses for the topics and subtopics – including all newly suggested subtopics. Due to the asynchronous nature of the system, experts are allowed to leave anytime and come back at a later time to complete the tasks.

As before in [18], we use a consensus building function to determine acceptance and rejection for each topic, subtopic, and proposed alternative name within the name analysis process. When we have at least 10 inputs, we will accept or reject topics with lower agreement (60% or higher). However, with 5 to 9 inputs we will accept or reject topics only with higher agreement (80% or more). If we have fewer inputs or less agreement, we will consider the topic as undecided. The consensus building function is constantly recalculated as input from the expert crowd is gathered dynamically, asking for inputs as long as we have low agreement. While the expert will be able to refine any topic/subtopic, the system will guide the expert to provide inputs towards low agreement or undecided decisions.

Results: Concluding the Consensus Building

Once round 2 of the experiment was completed, there was a total of 22 expert crowd participants providing a total of 8,177 inputs into Argupedia. 2,040 of those inputs were towards the confirmation or rejection of topics and subtopics where 170 were to confirm topics, 6 to reject topics, 950 to confirm subtopics, 38 to reject subtopics, 815 to confirm the newly suggested subtopics, 40 to confirm the newly suggested topics, and 21 to reject the newly suggested subtopics. These inputs resulted in all 8 of the baseline topics being accepted with high confidence by the expert crowd, all 44 baseline subtopics being accepted with high confidence by the expert crowd, 2 newly suggested topics, and 43 newly suggested subtopics by the members of expert crowd being accepted with high confidence by the totality of the expert crowd.

The consensus building function was also applied to the name analyses effort for each topic, subtopic, and newly suggested subtopic. 75% of the expert crowd's inputs (6,137) were processed for the name analyses feature. This included 259 proposed alternate renames of the baseline topics (22), baseline subtopics (104), newly suggested topics (104), and newly suggested subtopics (128) from the expert crowd. This also included 3,385 name analyses confirmation inputs, and 2,689 name analyses rejection inputs. These inputs resulted in 79 of the topics and subtopics having a name accepted with high confidence, 15 having a name accepted with low confidence, and 1 having a name rejected with low confidence due to the 42% confirmation rate.

Looking deeper at the name analysis with the 42% confirmation rate, the researchers saw that the overall newly suggested subtopic was accepted with high confidence. But because there were a total of six proposed alternate names for this subtopic, the consensus building function yielded only a 42% confirmation rate. That being said, a name needed to be chosen given that the subtopic was confirmed. Based on the subtopic, the course owner determined that the 42% confirmed proposed alternative name was the most appropriate for the subtopic.

Table 1 shows a comparison between the two previous experiments and this one. The experiments involve a crowd ranging from 15-22 experts, and shows the different amounts of inputs per experiment. All three experiments show a similar amount of newly suggested topics and subtopics from the expert crowd, with the experiments utilizing the consensus building function showing a higher number for suggestion confirmations. All three experiments also had a healthy number of proposed alternate names from the expert crowd, but only this experiment had the functionality with the consensus building function to determine which of the 259 proposed alternate names were ultimately chosen based on the expert crowd's consensus, which is also the reason for this experiment to have the highest amount of expert inputs. And finally, the results show that with more automation (consensus building for the data analysis of topics, subtopics, and name analyses) outputs a quicker data analyses duration.

Table 1 – Experiments 1 & 2 Comparisons

	Experiment 1 2 Rounds [21]	**Experiment 2a First Round [18]**	**Experiment 2b First & Second Round (This Experiment)**
Total Number of Experts	19	15	22
Total Number of Inputs	<300	1,555	8,177
Data Analysis of topics and subtopics	Manual	Consensus Building Function	Consensus Building Function

Newly suggested topics and subtopics	13 topics 29 subtopics	40 subtopics	2 topics 43 subtopics
Confirmation of new topics and subtopics	1 topic 3 subtopics	19 subtopics	2 topics 43 subtopics
Data Analysis of Proposed Alternate Names	Manual	Manual	Consensus Building Function
Proposed Alternate Names (Renames)	53	228	259
Confirmation of an Alternative Name	N/A	N/A	24
Total Time Spent on Data Analysis	6 hours	2-3 hours	Less than 1 hour

This experiment involving the consensus building function resulted in a revised curriculum for the course which can be seen in Appendix D.

Discussion: Concluding the Consensus Building

For both phases of Experiment 2, consensus between the experts were accomplished when using the consensus building function. When comparing the experiments, Experiment 2 is shown to have achieved consensus 50% faster when using the consensus building function than when using a commonly-used survey during Experiment 1. And due to the design of the dynamic crowdsourcing platform, the consensus building function was able to execute different types of operations. These include the identification of topics/subtopics (confirmations and rejections), creation of new ontological elements (suggesting a new topics/subtopics), naming of each ontological element (proposing an alternative name for a topic/subtopic), and the determination of a name per topic/subtopic (consensus on a topic/subtopic's name through name analysis). By providing these different types of operations, it gave experts the opportunity to supply a greater amount of input per expert engagement at their discretion. This resulted in a more detailed curriculum at the end of Experiment 2 (provided in Appendix D), compared with the baseline curriculum provided by the course instructor (Appendix B) and the academic committee curriculum (Appendix C).

Another important observation is that the curriculum structure will eventually plateau. When looking at the number of new subtopics suggested in Experiment 2a there were 40 subtopics by 15 experts, while the Experiment 2b added only 4 new subtopics by 7 new experts. This means that after Experiment 2a, the experts almost agreed on the needed subtopics. Similar results were related to naming of these subtopics. At the end of Experiment 2a there were 228 alternative names proposed for the subtopics (by 15 experts), while at the end of Experiment 2b there were only 31 more alternative names proposed by the 7 new experts. Because the 7 new experts in Experiment 2b had a greater interaction and provided more inputs than the expert in Experiment 2a, the results cannot be explained by less participation, and clearly indicate obtaining consensus and completeness for the curriculum.

Overall, when using the consensus building function along with the dynamic crowdsourcing platform, it showed the researchers how curriculum development efforts can be quickly done with a large amount of inputs from multiple domain experts – all while being completed asynchronously and with automated consensus achievement with confidence levels.

Defining the Professional Diversity Factor

However, what is lacking in the consensus algorithm and curriculum development space is the diversity aspect – specifically professional diversity. Kuhlman et al. [22] focus their article on race and gender diversity in the area of computer science, artificial intelligence, and machine learning – their points on the lack of race and gender diversity within the existing academic and professional computing field; its impact on the workforce and future generations; as well as potential improvement techniques to address the challenges are applicable to the lack of professional diversity in curriculum development efforts. [22] suggest that by connecting to a broader network of higher education institutions (higher education curriculum development), including stakeholders from diverse communities in the research process (crowdsourcing the experts), and creating opportunities within our own activities to support a diverse group of future leaders (including industry experts in the curriculum development process) – the field (cyber security management) and those affected by it (the students) will be better served.

The professional diversity measure provides a new factor in ensuring that a representative group with different professional backgrounds, years of experience, and industry sectors are considered when performing a group or crowdsourcing effort. This contribution is important in a variety of ways:

- The measure can be used to determine the current count/weight of professional diversity in the response pool.
- The measure can be used to determine how many additional responses are still required in order to achieve the effort's professional diversity goal.
- The achievement of professional diversity in curriculum development will enhance the relevance of the effort due to the respondents' different perspectives and their inputs.
- The professional diversity measure can be a factor for consideration in other decision-making processes involving a group/crowd beyond the curriculum development realm.

To calculate in the crowd's professional diversity and ensure there are enough representatives from various relevant categories of professional, the researchers used a five-step process: (1) Identify the relevant factors, (2) Identify the interactions between factors and relevant categories to consider, (3) Identify the relevance of the identified categories, (4) Identify the ideal recruitment needs, and (5) Compute a global diversity measure based on current recruitment.

Step 1: The researchers started by identifying relevant factors related to professional diversity, which will be used to represent statistical variables for the population. These factors were chosen (identified below) due to their close relation to an expert's professional career experience, expertise, qualifications, and sector in the target curriculum's domain [23], [24].

- ***Years of domain experience:*** This gauges an expert's duration in the area of interest as time can suggest experience. This can be collected as ranges (e.g., 0-5, 6-10, 11-15, 16-20, 20+).
- ***Education level:*** This gauges an expert's exposure to the domain's body of knowledge to include its standards, best practices, and vernacular. This can be collected as degree types (e.g., 2-year, 4-year, Graduate, or Terminal degrees) and certifications (e.g., Certified Information Security Manager, Certified Information Systems Security Professional).
- ***Level of Expertise:*** This gauges an expert's level of experience in the area of interest based on their job activities, roles, and responsibilities. These can be categorized as follows:
    - *Entry-level:* Understands foundational knowledge; Operator in the field
    - *Specialist:* Operator in the field; Helps train entry-level
    - *Subject Matter Expert:* Provides technical guidance; Mentors others in the field
    - *Leader:* Provides overall goals and visions for the field
- ***Percentage of work activities dedicated to the practice:*** This gauges an expert's amount of work effort relating to the domain's specific area of practice and activities. For example, Cybersecurity is a large domain, but Network Security would be a specific area of practice within the domain. These can be collected as ranges (e.g., 0%-10%, 11%-25%, 26%-50%, 51%-75%, 76%-90%, 91%-100%).
- ***The industry they practice within:*** This gauges the industry or environment an expert applies their efforts towards and could have expertise in terms of regulation, specific best practices, constraints, etc. (e.g., industry, government, education).
- ***The position they hold:*** This gauges the experts participating in the crowdsourcing effort and what they are currently working as according to their employment status, and can include the following categories:
    - *Trainer:* Instructor, Teacher, Professor
    - *Professional:* Analyst, Consultant, Engineer, Specialist, Researcher
    - *Managerial:* Supervisor, Manager, Director
    - *Leader:* C-Suite Executive, VP

Step 2: The identification of the interaction between the different factors and which combinations are then considered (if there are independent variables or dependent variables). For instance, the input of a junior engineer in industry versus an assistant professor in academia. Both are juniors but in different industries. One solution is to consider them as diversity categories: junior versus senior, or industry versus academia. Another solution is to consider the categories: junior in industry and junior in academia. If the factors are independent with respect to the subject matter, then keeping simple distinct categories will be easier. However, it may be determined that the views of a junior in industry are quite different from the views of a junior in academia, and therefore it's necessary to keep the combined categories (which will lead to more categories but also more accurate results). In this case, the factors will be dependent. Such an analysis will be performed both at the beginning using domain expertise but also during the experiment analyzing the answers received and adapting prior decisions.

Step 3: However, not all categories have the same contribution. Therefore, the researchers had to identify the relative relevance of the determined categories. For instance, the inputs from a junior respondent being as relevant as the inputs from a senior level respondent need to be determined. A senior level respondent may be more experienced and have more knowledge in principle and current best practices of the field, but it may also be the case that a junior level respondent may be more aware of the emerging technologies and environmental changes.

Step 4: By having categories, considering the number of respondents per category was be important. For instance, all the respondents should not only be from industry – there should be a balance between industry, government, and academia. Based on these numbers, the consensus building function is equipped to attach confidence levels to the category modifications. For example, if the curriculum is for undergraduates with the goal of making them prepared for industry and government careers, then perhaps a larger number of industry and government respondents should be emphasized / weighed / required (requested for input). However, if the curriculum is geared towards PhD students, then a larger respondent pool of academics may be desired.

Step 5: Finally, the creation of a global approximative professional diversity measure that unify all the above considerations in a single measure is needed. For instance, it may be regarded as a percentage from a desired goal (i.e., how much of the goal is achieved). The professional diversity factor calculation can be an impactful factor to address in consensus achievement of the expert crowd. The researchers start by proposing and evaluating a simple way to calculate the Global Professional Diversity (*PD*) measure, as a weighted sum of the diversity of each factor, and is constructed as a percent, having a value between 0 and 1:

$$PD = \sum_f (w_f D_f) \text{ with } \sum_f (w_f) = 1$$

In the formula, *f* represents a factor that is considered in the professional diversity. For each factor, we have the weight of the factor, w_f, as a percent and the diversity of the factor, D_f as another percent of achieving the diversity for that factor. The greater the PD, the more the crowd is professionally diverse. A PD=1 means that professional diversity of the crowd is achieved. To decide the weights, one may consider various strategies: elicit from experts in the field, start with equal weights and refine based on their impact, compute them based on prior data.

The diversity of a factor *f* is computed as a weighted sum of all potential value categories of that factor:

$$D_f = \sum_c (w_c D_c) \text{ with } \sum_c (w_c) = 1$$

For each factor we will consider all the categories of values and sum their weighted diversity. For each category *c*, we will have a weight, w_c, representing their percentage in the factor diversity. The sum of all weights must be normalized to one Also, we will have a measure of the diversity for that category, D_c. The factor diversity will be a number between 0 and 1, interpreted as the percent of obtaining diversity for that factor. Similar with the weight of factors, to determine the weight of categories one might use the above strategies, e.g., expert elicitation. The weights of categories for various factors are independent and may be computed differently.

To compute the diversity for a category, we may take in account how many experts in that category we have with respect to a desired number of experts in that category.

$$D_c = Min(1, \frac{N_a}{N_c})$$

The formula above computes the percentage of completion, by dividing the number of answers (N_a) received from the experts in that category, with the number of desired experts (N_c) to respond for said category. To keep D_c normalized the value should not be greater than 1, after reaching the desired number of answers, additional answers from the same category will not affect the PD. There are many ways to determine N_c, for instance, by considering a default value.

<u>Design of Experiment: The Professional Diversity Factor</u>

When running this final experiment (Experiment 3) with the professional diversity factor (PDF) consideration, which is an additional variable to be used in the consensus building function and dynamic crowdsourcing platform, the input and interaction process between the expert crowd and dynamic crowdsourcing platform stays the same as described in the previous "Design of Experiment" section. However, there are two additional processes in Experiment 3.

The first occurred when the individual expert consented to the experiment. When consenting to participate, the individual experts were required to provide their professional background demographics – which were described within "Step 1" of the "Defining the Professional Diversity Factor" section. This information was then transferred into the dynamic crowdsourcing platform once the expert's login credentials were created.

In this particular experiment, the researchers used three of the six factors collected. This was because the first two factors listed were the most specific to the given course's description and there was a limited number of experts that will participate (so the variables needed to be independent). The third factor was chosen to provide balance between the experts' work environments. The other professional diversity factors not included (e.g., Education Level) were more broad and applicable to the larger cybersecurity domain, which would have been beneficial only if there was a larger crowd participating in the experiment.

- Percentage of Work Activities as applicable to the course's description (0%-10%, 11%-25%, 26%-50%, 51%-75%, 76%-90%, 91%-100%)
- Level of Expertise as applicable to the course's description (Entry-level, Specialist, Subject Matter Expert, Leader)
- The Industry they practice within (Private Industry, Government, Education)

Then the researchers started the experiment by considering the three factors as independent (Percentage of Work Activities, Level of Expertise, and the Industry). Only after receiving the expert inputs and making small analysis after the experiment, can the researchers determine if combined factors are needed. The researchers started the experiment by considering equal weights both for factors and their value categories. Based on the registered number of experts, the researchers decided to consider as a minimum number of participants per category being 3.

While these were ad hoc decisions, they are a starting point for the research and the researchers will discuss how they propose to refine them after the evaluation of the experiment.

Participant Professional Diversity Composition

In terms of the expert crowd's composition, it should be noted that in Experiment 2, the experts were assigned ad-hoc. Thus, we did not consider the professional diversity factors when the experts were invited to contribute to Experiment 2 – specifically because the experiment focused solely on the consensus building algorithm. Then in Experiment 3, we tried to have minimal representation in all categories within the three factors of professional diversity. Table 2 shows the coverage per category for both experiments. It can be seen that the expert coverage per category is more uniformed in Experiment 3 for each of the three factors. However, we can see Experiment 2 has a serious bias for the private industry category within the industry factor and some bias in the subject matter expert and 26%-50% categories. In the professional diversity measure we avoid the bias by weighting each category equally, independent of how many respondents we have in it. The only risk is if we have under-representation, like in some of the categories in percentage of work activities. However, here we have 6 categories and therefore we will need significantly more participants to fully cover all of them.

Table 2 – Participant Professional Diversity Composition

Factor	Category	Experiment 2 (Consensus Building)	Experiment 3 (Professional Diversity)
Industry	Academia	2	10
	Government	2	9
	Private Industry	17	11
Percentage of Work Activities in the Area	0% - 10%	2	4
	11% - 25%	5	8
	26% - 50%	7	10
	51% - 75%	4	3
	76% - 90%	2	4
	91% - 100%	1	3
Level of Expertise in the Area	Entry-Level	3	9
	Specialist	5	6
	Subject Matter Expert	8	10
	Leader	5	7

Topic and Subtopic Selection based on Professional Diversity Factor

The initial goal was to use the consensus measure with the professional diversity factor to determine if a topic or subtopic is selected. However, there were very few decisions that reached consensus. Therefore, we introduced a new measure to determine how close we are to reaching consensus and named it consensus coverage. If we have enough participants to reach consensus in a category, the consensus measure and the consensus coverage are the same. If not, we weigh the consensus measure with the current coverage in that category (i.e., the number of experts that answered of the total number needed). This measure will tell us how close we are to obtain consensus. If consensus was obtained, based on our previous rule, of super-majority, this measure will have the value of 1. A lower value will show that we are close but did not reach consensus. To mitigate the situations in which we are close but not have yet consensus, we accepted expert decision as having consensus, for [0.9-1.0] coverage.

As expected, sometimes the consensus measure with and without diversity will get the same decision and sometimes the decision will be different. While analyzing the data, it was observed that there were multiple different concluding outcomes (topic and subtopic acceptance / confirmation) depending on whether the consensus was determined based on the number of experts that confirmed like in Experiment 2 (which is referred to as “Consensus without PDC” in Table 3) or on the professional diversity’s coverage (PDC) like in Experiment 3 (which we referred to as “Consensus Coverage with PDC” in Table 3). The outcomes are as follows:

- The first row in Table 3 shows a topic that would be included in the curriculum when using both the “Consensus without PDC” and “Consensus Coverage with PDC” with 100% agreement. Row 1 of Table X shows an example of this.
- The topic/subtopic in the second row would be included in the curriculum when using both the “Consensus without PDC” (as more than 80% experts accepted the topic and over 10 responded), as well as the “Consensus Coverage with PDC” because we have at least 90% agreement
- The topic/subtopic in the third row would be included in the curriculum when using both the “Consensus without PDC” (as more than 60% of the experts accepted the topic and more than 20 responded), as well as “Consensus Coverage with PDC” with at least 90% agreement.
- The topic/subtopic in row four would be not be included in the curriculum both based on “Consensus without PDC” as it is less than 60% and the “Consensus Coverage with PDC” as it is less than 90%.
- The topic/subtopic in row five show different decisions, it would be included in the curriculum using the “Consensus without PDC” with at least 80% at 10 answers, but not when using the “Consensus Coverage with PDC” due to being less than 90%.

Table 3 – Sample Examples of Consensus Measures

Row #	**Topic / Subtopic**	**Consensus Without PDC**	**Consensus With PDC**	**Consensus Coverage Without PDC**	**Consensus Coverage With PDC**	**Included in Curriculum**

1	***Examination of Past Network, Data, & Application Security-Related Attacks***	100%	100%	100%	100%	Yes
2	***Security Testing***	84%	83%	100%	92%	Yes
3	***Quantum Cryptography***	77%	76%	100%	93%	Yes
4	***Peer-to-Peer Networking (P2P, Nodes)***	54%	55%	90%	70%	No
5	***Cloud Cryptography***	80%	77%	100%	89%	No

Results: The Professional Diversity Factor

In the final experiment (Experiment 3), a total of 31 experts participated in the crowdsourcing effort providing a total of 9,432 inputs into Argupedia. 3,081 of those inputs were towards the confirmation or rejection of topics and subtopics where 249 were to confirm topics, 5 to reject topics, 1,271 to confirm subtopics, 84 to reject subtopics, 149 to confirm newly suggested topics, 59 to reject newly suggested topics, 996 to confirm the newly suggested subtopics, and 268 to reject the newly suggested subtopics. These inputs resulted in consensus and rejection of multiple topics, subtopics, suggested new topics, and suggested new subtopics for the baseline curriculum. 7 of the 8 baseline topics being accepted with 100% coverage in terms of the expert crowd's professional diversity, and the 8th baseline topic being accepted in terms of professional diversity with at least 90% coverage. 12 of the 44 baseline subtopics were accepted with 100% coverage in terms of the expert crowd's professional diversity, and 32 of the 44 were accepted in terms of professional diversity with at least 90% coverage. There were also 8 newly suggested topics (5 of which were accepted in terms of professional diversity with at least 90% coverage) and 49 newly suggested subtopics (29 of which were accepted in terms of professional diversity with at least 90% coverage).

The professional diversity measure was also factored into the consensus building function for the name analysis effort for each topic, subtopic, and newly suggested topic and subtopic. 67% of the expert crowd's inputs (6,351) were processed for the name analyses feature. This included 230 proposed alternate renames of the baseline topics (37), baseline subtopics (61), newly suggested topics (29) and newly suggested subtopics (103) from the expert crowd. This also included 4,201 name analyses confirmation inputs and 2,150 name analyses rejection inputs. These name analysis inputs resulted in 16 total renames (1 topic, 3 subtopics, 2 new topics, and 10 new subtopics).

Table 4 shows a comparison between the three experiments. Experiment 3 has the most expert participants compared to the other experiments, and resulted in the highest number of inputs produced. This also resulted in a higher number of topics and subtopics being suggested. However, due to the professional diversity factor being applied within the consensus building function, only 5 out of the 8 newly suggested topics and 29 out of the 49 newly suggested topics were confirmed to be added to the curriculum. Similarly, due to the professional diversity factor, the number of proposed alternative names per topic and subtopic confirmed was also less than in Experiment 2. And like in Experiment 2's discussion, the results show that with more automation (consensus building for the data analysis of topics, subtopics, and name analyses) outputs a quicker data analyses duration.

Table 4 – Experiments 1, 2, & 3 Comparisons

	Experiment 1 [21]	**Experiment 2 [18]**	**Experiment 3**
Total Number of Experts	19	22	31
Total Number of Inputs	<300	8,177	9,432
Total Number of Sessions	38	41	43
Average inputs per person | session	15.8 | 7.9	371 | 199	304 | 219
Data Analysis of topics and subtopics	Manual	Consensus Building Function	Consensus Building Function with the Professional Diversity Factor
Newly suggested topics and subtopics	13 topics 29 subtopics	2 topics 43 subtopics	8 topics 49 subtopics
Confirmation of new topics and subtopics	1 topic 3 subtopics	2 topics 43 subtopics	5 topics 29 subtopics
Rejection of new topics and subtopics	Not Tracked	0	0
Undecided of new topics and subtopics	Not Tracked	0 topics 0 subtopic	3 topics 20 subtopics
Data Analysis of Proposed Alternate Names	Manual	Consensus Building Function	Consensus Building Function with the Professional Diversity Factor
Proposed Alternate Names (Renames)	53	259	230
Confirmation of an Alternative Name	N/A	24	16
Total Time Spent on Data Analysis	6 hours	Less than 1 hour	Less than 1 hour

This experiment involving the consensus building function resulted in a revised curriculum for the course which can be seen in Appendix E.

Name Selection based on the Professional Diversity Factor

The expert crowd also provides confirmation and rejection inputs for the potential naming of each topic and subtopic as well. The number of inputs can be overwhelming if processed manually, but with the crowdsourcing platform, the aggregation is instantaneous. A summary of the inputs provided by the expert crowd specific to the name analysis for the topics and subtopics is shown in Table 5.

Table 5 – Number of Name Analysis Inputs for Experiments 2 and 3

	Experiment 2 Expert Crowd (22 Domain Experts)					Experiment 3 Expert Crowd (31 Domain Experts)				
	Topics & Subtopics		Name Analysis of Topics & Subtopics			Topics & Subtopics		Name Analysis of Topics & Subtopics		
	Confirm	*Reject*	*Confirm*	*Reject*	*Renames*	*Confirm*	*Reject*	*Confirm*	*Reject*	*Renames*
Topics	170	6	269	266	22	249	5	568	452	37
Subtopics	910	38	1501	1064	104	1271	84	1913	783	61
New Topics	40	0	65	48	5	149	59	279	200	29
New Subtopics	855	21	1550	1311	128	996	268	1441	715	103

For Experiment 3, once a topic or subtopic is chosen based on the PDC confirmation being at least 90%, the name with the highest PDC confirmation is selected as the official name for that topic or subtopic. If two names have PDC of 1 then the consensus measure is used as a tie. In most cases the selected name will also have a PDC confirmation of at least 90%, but in some instances that is not the case and the highest PDC confirmation will be the selected default. On occasion, it was observed that the PDC confirmation selected ("Consensus Coverage with PDC") was not greater than the highest "Consensus without PDC" (the output for the consensus building algorithm when not having the professional diversity factor applied – used in Experiment 2). When this occurs, it suggests that additional expert participation in one or more of the professional diversity categories is required.

Discussion: The Professional Diversity Factor

A major observation in Experiment 3 was that the professional diversity factor increased the threshold for overall confirmation of any ontological element. In other words, it required more participants to contribute (and agree) to each topic, subtopic, newly suggested topic, and newly suggested topic before they can be determined as confirmed. This can be seen in the number of undecided (neither a confirmation or a rejection) in Experiment 3 (3 topics and 20 subtopics) when compared to Experiment 2 (0 undecided). This can also be seen in the confirmation of a proposed alternative name, since it also applies the professional diversity factor to the consensus building function (16 confirmed in Experiment 3 compared to 24 confirmed in Experiment 2). This is also why there were 31 expert participants in Experiment 3 compared to 22 in Experiment 2.

In both experiments, there were around 40 sessions with 86% of the participants in Experiment 2 having a second phase but only around 42% of the participants in Experiment 3 having a second phase. This difference was the result of expert selection method used with the goal of having around the same time of expert elicitation in both experiments. Through this observation, it can be determined that there were about 371 inputs per person on average in Experiment 2 and 304 inputs per person on average in Experiment 3. While there were more inputs per person on average in Experiment 2, the inverse is true when looking at the average inputs per session for the two experiments – there were 199 inputs per session on average in Experiment 2 compared to the 219 inputs per session on average in Experiment 3. We conclude that while we had around the same elicitation time in both experiments, Experiment 3 received more input from more participants.

Another important observation in Experiment 3 was that only 7 topics and 12 subtopics were confirmed with 100% coverage when considering the professional diversity factor. The remaining confirmed topic (1), subtopics (32), and all of the newly suggested items (5 topics and 29 subtopics) had a professional diversity factor coverage between 90% and 99%. This also led to 23 of the newly suggested topics and subtopics receiving a status of undecided instead of confirmed or reject (there were 0 undecided for Experiment 2). A greater number of expert participants would be needed to increase the professional diversity's confirmation coverage (assuming those additional experts would confirm the topics and subtopics) in order to achieve 100% professional diversity coverage confirmation.

Table 6 - Consensus without and with Professional Diversity Coverage (PDC)

Weak Consensus Analysis	**Experiment 2 (Without PDC)**	**Experiment 3 (With PDC)**		
	Accepted (100%)	Accepted (100%)	Accepted (>=90%; <100%)	Undecided
Topics	8	7	1	0
Subtopics	44	12	32	0
New Topics	2	0	5	3
New Subtopics	43	0	29	20

Overall, applying the professional diversity factor when using the consensus building function along with the dynamic crowdsourcing platform showed the researchers how curriculum development efforts can be quickly done with a large amount of inputs from multiple domain experts of varying skill level and experiences (professionally diverse) – all while being completed asynchronously and with automated consensus achievement based on confidence levels. It also showed that the level of difficulty to achieve consensus achievement with 100% professional diversity coverage is much higher than when compared to only consensus achievement. Thus, the professional diversity factor (Experiment 3) can better prioritize consensus among the experts due to the higher threshold required to achieve consensus, versus solely depending on the consensus building function (Experiment 2) where a greater than or equal to 60% is all that is necessary.

Conclusion

The outcomes of Experiment 2 and Experiment 3 demonstrated that curriculum development can be done effectively through asynchronous crowdsourcing beyond utilizing the typical curriculum committee. These two experiments were made possible through a platform that allows for dynamic crowdsourcing, where domain experts were able to interact and utilize the tool in an asynchronous environment. The crowdsourcing platform allowed the experts to confirm, reject, and rename topics and subtopics; as well as suggest new topics and subtopics.

Experiment 2 focused on determining the impact of implementing a consensus building function within the crowdsourcing platform. The results demonstrated that consensus was able to be achieved among the experts, and at a high rate of consensus. For example, all the topics (8), subtopics (44), newly suggested topics (2), and newly suggested subtopics (43) were confirmed with high confidence by the expert crowd through the consensus building function.

Experiment 3 extended this effort by integrating a professional diversity factor into the consensus building function and demonstrated while consensus achievement is still possible, it will require more experts to achieve consensus depending on how many professional diversity categories are used. This resulted in a professional diversity consensus coverage measure to show the researchers how close each topic and subtopic are to consensus or rejection. The measure ensure that not only is a supermajority needed from the expert crowd, but that the expert crowd themselves are properly represented in terms of professional diversity. Moreover, in this experiment the professional diversity representation is equally weighted across three categories, to avoid bias by over representation.

Path Forward

Now that the experiment is completed, and there are four curriculum variations for the new graduate course, the evaluation of the four different curriculums by industry professionals to see which one is the most relevant to the industry today is necessary. The four curriculums would be the baseline curriculum created by the curriculum owner, the academic curriculum, the curriculum resulting from the consensus building function, and the curriculum resulting from the consensus building function with the professional diversity factor applied.

It should be noted that this experiment (consensus building and consensus building with the professional diversity factor) has only been done with one graduate-level course. A natural next step would be to conduct the experiment on two more graduate-level courses, followed by a few undergraduate course for comparison of the results. Additional experimentation on the professional diversity factor to determine the optimal number of factors, categories, and experts should also be looked at.

In terms of the crowdsourcing platform, there are many enhancement suggestions that were brought up by the expert crowd including creating features that allow for the ordering of the topics and subtopics as desired by the expert crowd; allowing for experts to provide comments for each topic and subtopic to clarify their thoughts if necessary; allowing for the moving of subtopics from one topic to another if desired; and some other usability features as suggested by the expert crowd such as a progress bar.

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Appendix A

Baseline Curriculum

Managing Network and Data Security

Target Audience: Graduate Students in the School of Business

Description: The course covers principles and practices of assessing network and data security needs, and implementation of the necessary security plan for communication networks and organizational data. The course addresses databases as well as unstructured data in files, including securing cloud infrastructure. More specifically, the course will focus on database security principles, database auditing, database reliability and implementation of database controls and security. In context of CIA triad of information security, threat classifications to the communication networks are discussed: eavesdropping (confidentiality), man-in-the-middle (integrity), and denial-of-service (availability). Real world examples of attack methods and cases of database breaches are discussed, as well as attacks on communication networks and networked applications are discussed to translate principles into reality. Security design and architecture consisting of authentication, authorization, access control, traffic monitoring, secure protocols are covered. Class project requires students to undertake security requirements assessment, conduct an audit and present a network and data security plan.

Course is set for Eight Weeks

Pre-requisite Courses

Database Management Systems (or equivalent)
AND
Networks & Security (or equivalent)

Corequisite Course

Fundamentals of Information Security Management*

***Topics Taught in Fundamental of Information Security Management:**

1. The Cyber Environment & Current / Emerging Threats
2. Information Security Fundamentals & Principles
3. Identity & Access Management
4. Host Hardening & Vulnerability Assessments
5. Supply Chain Cyber Security Overview
6. Cloud Security & Managed Security Service Providers
7. Framework & Architecture: Cyber Security, Risk Management, & Zero Trust
8. Incident Response & Business Continuity

Appendix B

Baseline Curriculum

Managing Network and Data Security

Topics & Subtopics

1. Review of IT Networking & Database Management Fundamentals
    - IT Networking Technologies
    - IT Networking Protocols
    - OSI Reference & TCP/IP Network Models
    - Database Design Fundamentals
    - Database Technologies & Systems
    - Structured Query Language Basics
2. Examination of Past Network, Data, & Application Security-Related Attacks
    - Target Security Incident (2013)
    - U.S. Office of Personnel Management Security Incident (2015)
    - Equifax Security Incident (2017)
    - Marriott Security Incident (2018)
    - Colonial Pipeline Security Incident (2021)
    - SuperVPN, GeckoVPN, & ChatVPN Security Incident (2022)
3. Securing Applications & Their Data
    - Data Discovery, Classification, & Valuation
    - Securing Databases & User Devices
    - Access Control to the Data
    - Security of Data Backups & the Restoration Process
    - Data Retention & Disposal
    - Application Security: OWASP Top 10
4. Securing Communications & Networks
    - Network Security Basics: Firewalls; Intrusion Detection & Prevention Systems
    - Securing Network Hardware
    - Access Control to the Network
    - Securing Network Traffic
    - Virtual Private Networks
    - Securing & Auditing Network Operations
5. Cryptography & Encryption
    - Cryptography Basics: Hashes; Symmetric & Asymmetric Cryptography; Hybrid Cryptography
    - Encryption at Rest & in Transit; IPsec
    - Encryption Algorithms
    - Quantum Cryptography

6. Network & Data Security in the Cloud
    - Overview of Cloud Computing
    - Security Benefits in the Cloud Environment
    - Security Challenges in the Cloud Environment: Lack of Visibility, Multitenancy, & Misconfigurations
    - Implementing on-premises Security Solutions in the Cloud Environment
7. Architecting Network & Data Security Design
    - Requirements Determination with Business Stakeholders
    - Unified Threat Management (UTM)
    - Endpoint Protection & BYOD
    - Data Loss/Leak Prevention (DLP)
    - Zero-Trust Security Design
    - Physical Security of Networks, Data Centers, & Devices
8. Managing Network & Data Security Operations
    - Configuration Management: Change & Patch Management
    - Managing Exceptions in Network & Data Security
    - Security Information & Event Management (SIEM)
    - Managed Security Service Providers (MSSPs)
    - Automated Continuous Auditing, Compliance Checking, & Vulnerability Assessment
    - Continuous Improvement of Network & Data Security

Appendix C

Academic Committee's Curriculum

Managing Network and Data Security

Topics & Subtopics

1. Review of IT Networking & Database Management Fundamentals
    a. IT Networking Technologies
    b. IT Networking Protocols
    c. OSI Reference & TCP/IP Network Models
    d. Database Design Fundamentals
    e. Database Technologies & Systems
    f. Structured Query Language Basics
2. Examination of Past Network, Data, & Application Security-Related Attacks
    a. Target Security Incident (2013)
    b. U.S. Office of Personnel Management Security Incident (2015)
    c. Equifax Security Incident (2017)
    d. Marriott Security Incident (2018)
    e. SolarWinds Security Incident (2019)
    f. Colonial Pipeline Security Incident (2021)
    g. SuperVPN, GeckoVPN, & ChatVPN Security Incident (2022)
3. Securing Databases
    a. Data Discovery, Classification, & Valuation
    b. Database Security Threats: (i.e. SQL Injection)
    c. Securing Databases & SQL Security Commands: GRANT, REVOKE, VIEW, etc.
    d. Database Reliability: Security of Data Backups & the Restoration Process
    e. Data Retention & Disposal
    f. Database Auditing
    g. Application Security's Impact on Database Security: OWASP Top 10
    h. Securing Unstructured Data
4. Securing Communications & Networks
    a. Network Security Basics: Firewalls; Intrusion Detection & Prevention Systems
    b. Common Network Threats: Eavesdropping, man-in-the-middle, & denial-of-service
    c. Securing Network Hardware
    d. Securing Network Traffic
    e. Virtual Private Networks
    f. Securing & Auditing Network Operations
5. Cryptography & Encryption
    a. Cryptography Basics: Hashes; Symmetric & Asymmetric Cryptography; Hybrid Cryptography
    b. Encryption at Rest & in Transit; IPsec

    c. Encryption Algorithms
    d. Overview & Impacts of Quantum Cryptography
6. Network & Data Security in the Cloud
    a. Security Benefits in the Cloud Environment
    b. Security Challenges in the Cloud Environment: Lack of Visibility, Multitenancy, & Misconfigurations
    c. Implementing on-premises Security Solutions in the Cloud Environment
7. Designing & Architecting Network & Data Security
    a. Requirements Determination with Business Stakeholders
    b. Unified Threat Management (UTM)
    c. Endpoint Protection & BYOD
    d. Data Loss/Leak Prevention (DLP)
    e. Zero-Trust Security Design
    f. Physical Security of Networks, Data Centers, & Devices
    g. Planning Security Implementations & Upgrades
8. Managing Network & Data Security Operations
    a. Configuration Management: Change & Patch Management
    b. Managing Exceptions in Network & Data Security
    c. Security Information & Event Management (SIEM)
    d. Managed Security Service Providers (MSSPs)
    e. Automated Continuous Auditing, Compliance Checking, & Vulnerability Assessment
    f. Continuous Improvement of Network & Data Security

Appendix D

Consensus Building Function Curriculum

Managing Network and Data Security

Topics & Subtopics

1. Review of IT Networking & Database Management Fundamentals
    a. IT Networking Technologies
    b. IT Networking Protocols
    c. OSI Reference & TCP/IP Network Models
    d. Database Design Fundamentals
    e. Database Technologies & Systems
    f. Structured Query Language Basics
    g. Analysis of Cyber Security Vulnerabilities/Exploits
2. Examination of Past Network, Data, & Application Security-Related Attacks
    a. Target Security Incident (2013)
    b. U.S. Office of Personnel Management Security Incident (2015)
    c. Equifax Security Incident (2017)
    d. Marriott Security Incident (2018)
    e. Colonial Pipeline Security Incident (2021)
    f. SuperVPN, GeckoVPN, & ChatVPN Security Incident (2022)
    g. Incident Response Roles and Responsibilities, and Communications Strategies
    h. SolarWinds U.S. Supply Chain Attack in 2020
    i. Fish Tank Thermometer Exploit in Las Vegas
    j. LinkedIn User Data Compromise (2021)
    k. Open AI ChatGPT Data Breach (2023)
    l. Log4j Third Party Library Security Incident
    m. Capital One (2019)
    n. Analysis of Cyber Exploits and Techniques
    o. MITRE ATT&CK for Enterprise IT and ICS
3. Application and Data Security
    a. Data Discovery, Classification, & Valuation
    b. Securing Databases & User Devices
    c. Data Access Control
    d. Security of Data Backups & the Restoration Process
    e. Data Retention & Disposal
    f. Web Application Security: OWASP Top 10
    g. Endpoint Security
    h. Database Attack Methods and Mitigation
    i. Secure Application Design: Software Development Life Cycle (SDLC)
    j. Methods to discover vulnerabilities in applications (Penetration testing, SAST, DAST, SCA, etc.)
4. Securing Communications & Networks

    a. Network Security Basics: Firewalls; Intrusion Detection & Prevention Systems
    b. Securing Network Hardware
    c. Network Access Control and Management
    d. Securing Network Traffic
    e. Virtual Private Networks
    f. Securing & Auditing Network Operations
    g. Encryption for Data In Transit
    h. Identity and Authentication Methods
5. Cryptography & Encryption Fundamentals
    a. Cryptography Basics: Hashes; Symmetric & Asymmetric Cryptography; Hybrid Cryptography
    b. Encryption at Rest & in Transit; IPsec
    c. Encryption Algorithms
    d. Quantum Cryptography
    e. Homomorphic Encryption
    f. Tokenization
    g. Hashing + Salt
    h. Kerberos
    i. PKI and CA fundamentals
6. Cloud Security
    a. Overview of Cloud Computing
    b. Security Benefits in the Cloud Environment
    c. Security Challenges in the Cloud Environment
    d. Implementing on-premises Security Solutions in the Cloud Environment
    e. Public Cloud Security Capabilities
    f. Cloud Concepts, Architecture and Design
    g. Cloud Security Operations
    h. Cloud Data Security
    i. SDLC process in a Cloud Environment
    j. Regulations & Security Standards in Cloud Environments
7. Network Architecture and Data Security Design
    a. Requirements Determination with Business Stakeholders
    b. Unified Threat Management (UTM)
    c. Endpoint Protection & BYOD
    d. Data Loss/Leak Prevention (DLP)
    e. Zero-Trust Security Design
    f. Physical Security of Networks, Data Centers, & Devices
    g. Data Integrity Systems
    h. Security Operations
    i. Meeting Security Standards (FISMA, FEDREF, ISO)
    j. Server & Device Hardening
    k. Identifying and Controlling Network Boundaries
    l. Network Segmentation/Segregation
    m. Security Compliance (GDPR, ISO 27001, SOC 2)
    n. Threat Modeling
    o. Availability and Disaster Recovery

   p. Incident Response & Recovery
8. Managing Network & Data Security Operations
   a. Configuration Management: Change & Patch Management
   b. Managing Exceptions in Network & Data Security
   c. Security Information & Event Management (SIEM)
   d. Managed Security Service Providers (MSSPs)
   e. Automated Continuous Auditing, Compliance Checking, & Vulnerability Assessment
   f. Continuous Improvement of Network & Data Security
   g. Establishing, Maintaining and Validating a Network Map, and Monitoring for Rogue Devices
   h. Digital Forensics
   i. Incident Response Planning & Implementation
   j. Disaster Recovery Plans (DRP)
   k. Security Operation Centers (SOC)
9. Risk Management & Communicating Risks
10. Hardware Security

Appendix E

Consensus Building Function with the Professional Diversity Factor Curriculum

Managing Network and Data Security

Topics & Subtopics

1. Review of IT Networking & Database Management Fundamentals
    a. IT Networking Technologies
    b. IT Networking Protocols
    c. OSI Reference & TCP/IP Network Models
    d. Database Design Fundamentals
    e. Database Technologies & Systems
    f. Structured Query Language Basics
2. Examination of Past Network, Data, & Application Security-Related Attacks
    a. Target Security Incident (2013)
    b. U.S. Office of Personnel Management Security Incident (2015)
    c. Equifax Security Incident (2017)
    d. Marriott Security Incident (2018)
    e. Colonial Pipeline Security Incident (2021)
    f. SuperVPN, GeckoVPN, & ChatVPN Security Incident (2022)
    g. SolarWinds (2020)
    h. WannaCry Ransomware Attack (2017)
    i. Okta Cyber Breach
    j. Stuxnet: A Case Study on Nation-State Cyberweapons
3. Securing Applications & Their Data
    a. Data Discovery, Classification, & Valuation
    b. Securing Databases & User Devices
    c. Access Control to the Data
    d. Security of Data Backups & Disaster Recovery
    e. Data Retention & Disposal
    f. Application Security: OWASP Top 10
    g. Application Vulnerabilities
    h. Security Testing
4. Securing Communications & Networks
    a. Network Security Basics: Firewalls; Intrusion Detection & Prevention Systems
    b. Securing Network Hardware
    c. Access Control to the Network
    d. Securing Network Traffic
    e. Virtual Private Networks
    f. Securing & Auditing Network Operations

    g. Wireless Security Basics
    h. Network & System Monitoring
    i. Endpoint Detection and Response
    j. Endpoint Management
    k. Network Segmentation
5. Cryptography & Encryption Fundamentals
    a. Cryptography Basics: Hashes; Symmetric & Asymmetric Cryptography; Hybrid Cryptography
    b. Encryption at Rest & in Transit
    c. Encryption Algorithms
    d. Quantum Cryptography
    e. Encryption Algorithm Vulnerabilities
    f. Legacy Encryption: Security Vulnerabilities in Future Systems
    g. Symmetric and Asymmetric Encryption
    h. Digital Signatures and Certificates
    i. Public Key Infrastructure
6. Network & Data Security in the Cloud
    a. Overview of Cloud Computing
    b. Security Benefits in the Cloud Environment
    c. Security Challenges in the Cloud Environment
    d. Implementing on-premises Security Solutions in the Cloud Environment
    e. Cloud Service Components Overview: Containerization, Orchestration, Authentication
    f. Local Cloud Architecture vs Commercial Virtualized Architecture
    g. Cloud Security Considerations for Data Sovereignty
    h. Multicloud Architecture (AWS, GCP, and Azure)
    i. Private / Public / Hybrid Cloud Architecture
7. Data and Network Security Design
    a. Requirements Determination with Business Stakeholders
    b. Unified Threat Management (UTM)
    c. Endpoint Protection & BYOD
    d. Data Loss/Leak Prevention (DLP)
    e. Zero-Trust Security Design
    f. Physical Security of Networks, Data Centers, & Devices
    g. Defense-In-Depth
    h. Security Information and Event Management (SIEM) Systems
    i. Virtual Private Networks and Secure Network Design
8. Managing Network & Data Security Operations
    a. Configuration Management: Change & Patch Management
    b. Managing Exceptions in Network & Data Security
    c. Security Information & Event Management (SIEM)
    d. Managed Security Service Providers (MSSPs)

   e. Automated Continuous Auditing, Compliance Checking, & Vulnerability Assessment
   f. Continuous Improvement of Network & Data Security
   g. Security Technical Implementation Guide (USGS, Classified Systems)
   h. Penetration Testing
   i. Business Continuity and Disaster Recovery
   j. Third-party Risk Management and IT Supply Chain Security Management
9. IOT Network Security
10. Managing Risk in the Enterprise
11. Identity and Access Management
12. Secure Application Development
13. Governance, Risk, and Compliance