Board 348: NSF Grantees Poster Session: Power Engineering Curriculum Update: Preliminary Evaluation of Student Concept Maps on Energy Forecasting

Dr. Courtney S. Smith-Orr, University of North Carolina, Charlotte

Courtney S. Smith, PhD is a Undergraduate Coordinator & Teaching Assistant Professor at UNC Charlotte. Her research interests span the mentoring experiences of African American women in engineering,minority recruitment and retention, and best practices for

Prof. Valentina Cecchi, University of North Carolina, Charlotte

Valentina Cecchi is originally from Rome, Italy. She attended Drexel University in Philadelphia, PA, where she completed B.S., M.S., and Ph.D. degrees in Electrical Engineering in 2005, 2007, and 2010, respectively. She joined UNC Charlotte in 2010 as Ass

Dr. Paras Mandal, The University of Iowa

Paras Mandal is an Assistant Professor of industrial, manufacturing, and systems engineering at the University of Texas, El Paso. Mandal obtained a doctoral degree in interdisciplinary intelligent systems engineering. His teaching and research interests i

Sukumar Kamalasadan

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Power Engineering Curriculum Update: Preliminary Evaluation of Student Concept Maps on Energy Forecasting

C. Smith-Orr*, V. Cecchi*, P. Mandal, S. Kamalasadan***

* Electrical & Computer Engineering Dept.
The University of North Carolina at Charlotte

** Electrical & Computer Engineering Dept.
The University of Texas at El Paso

I. Introduction and Overview

In order to better comprehend the depth and breadth of understanding that students have about a specific topic requires the use of strategic assessments. In this project, concept maps have become the tool of choice in learning how students conceptualize the dynamic of energy forecasting. Within this paper we will discuss the methods used to evaluate such concept maps and present some preliminary data of student concept maps on forecasting in the context of electric power systems.

This work is a small portion of an NSF IUSE-funded project to improve the undergraduate power and energy curriculum at two collaborating universities. The focus of this improvement is to incorporate developing topics in the field that are not currently integrated into the curriculum. New modules that utilize situative and active learning pedagogy have been developed. Therefore, the use of concept maps is being employed to enable students a way to provide a comprehensive picture of how they visualize and draw connections in and across the concepts being learned.

II. Methods

In preparing for the incoming data that would be produced from the concept maps, the research team initially intended to rely on the concept map rubric developed by Besterfield-Sacre [1] and the work of other researchers within Engineering Education [2]. In investigating the prior work, it was determined that modifications would need to be made to the original Besterfield-Sacre rubric to better fit the context of this research. The team developed a modified rubric and included a list of terms for the specific concept that would be used in evaluation [3]. Table 1 below shows the developed rubric. In conjunction with the rubric, to better aid the research team in evaluating the comprehensiveness of each map, a list of key terms describing this concept was provided by one of the faculty experts on the research team, Table 2.

Table 1. Modified Concept Map Scoring Rubric [3]

	1	1.5	2	2.5	3
Comprehensiveness covering completely/broadly Use the below terms to help determine comprehensiveness	The map lacks subject definition; the knowledge is very simple and/or limited. Limited breadth of concepts (i.e. minimal coverage of the topic). The map barely covers some of the qualities of the subject area.	The map has a combination of the features outlined in 1 and 2. Does not fit well into either category.	The map has adequate subject definition but knowledge is limited in some areas. Map suggests a somewhat narrow understanding of the subject matter.	The map has a combination of the features outlined in 2 and 3. Does not fit well into either category.	The map completely defines the subject area. The content lacks no more than one extension area.
Organization to arrange by systematic planning and united effort	The map is arranged with concepts only linearly connected. There are few (or no) connections within/between the branches. Concepts are not well integrated.	The map has a combination of the features outlined in 1 and 2. Does not fit well into either category.	The map has adequate organization with some within/between branch connections. Some, but not complete, integration of branches is apparent. Feedback loops *may* exist, if applicable.	The map has a combination of the features outlined in 2 and 3. Does not fit well into either category.	The map is well organized with concept integration and the possible use of feedback loops, if applicable. Sophisticated branch structure and connectivity.
Correctness conforming to or agreeing with fact, logic or known truth	The map is naïve and contains misconceptions about the subject area; inappropriate words or terms are used. The map documents an inaccurate understanding of certain subject matter.	The map has a combination of the features outlined in 1 and 2. Does not fit well into either category.	The map has few subject matter inaccuracies; most links are correct.	The map has a combination of the features outlined in 2 and 3. Does not fit well into either category.	The concepts that are present are integrated properly and reflect an accurate understanding of subject matter, meaning little or no misconceptions.

Table 2. List of Terms to be considered for Comprehensiveness

List 1: Low-Tier	List 2: Mid-Tier (Includes List 3)	List 3: High-Tier (Includes List 2 & 3)
Forecasting	Load Price Wind PV Temperature	
Quantitative Method	*Panel of Experts*	
Qualitative Method	Historical Data	
	Forecasting Steps:	
	1. Collect Historical Data	
	2. Pre-process Historical Data/Correlation Analysis	
	3. Identify Parameters	
	o Time	Seasonal Daily Weekly Holidays
	o Price	
	o Weather	Most Influential -> Temperature Precipitation Clouds Wind Speed Light Intensity
	o Random Disturbances:	Outages Holidays Sports
	o Economical	Industrial Commercial Residential
	o Other Factors	Geographical Location/Conditions
	4. Develop Forecasting Model	
	Machine Learning	Neural Network
	o Design architecture	Input Layers Hidden Layers Output Layers Neurons
	o Train Models	Regression Lines Other Training Algorithms
	5. Perform Forecasting Task	
	Forecast	
	o Very Short-Term and Short-Term	Minute-Ahead Hour-Ahead Day-Ahead Week-Ahead
	6. Analyze Output	
	Analyze Performance of forecast Models.	
	o Errors	MAPE RMSE/NRMSE MAE/NMAE Variance Standard Deviation

III. Data Collection

The implementation of new modules into relevant courses began in Spring 2022. Changes were implemented in a single course on each campus: 1. Power Generation, Operations, and Control, and 2. Power Systems Operations. In order to have a baseline understanding of students' level of understanding of these concepts before the new module was implemented, a pre-concept map was collected. Students were consented for their participation, provided a brief video tutorial on how to utilize a concept map making software and the basics of a concept map development and important characteristics that it should include. Students were given 20 minutes to complete their concept maps before submitting. A post- concept map was also created by students at the end of the semester to provide insight on any changes in their understanding.

IV. Data Analysis & Preliminary Results

Once data was collected and de-identified the research team assigned two of the faculty researchers involved in teaching the courses to grade each map. Table 3, provided below, shows only the scores from one institution in the Power Systems Operations course. In summary, before the new module was introduced the students in the course were given an average score of 6.23 on their concept maps. One expert did note that the students seemed to have fairly advanced knowledge of power systems operation prior to the introduction of the module. After completing the new module, the students averaged a score of 7.57. This scoring seems to demonstrate an enhanced understanding of the concept, as desired. Unfortunately, all students who participated in the pre-concept map did not opt to participate in the pos-concept map assessment. Additionally, one student seemed to have misinterpreted the assignment in the post-concept map phase and did not provide a concept map that was relevant to the assessment. This resulted in a sample size, for this term and this course, of 13 students.

To provide a more nuanced visual of the evolution from one point to the next, a single student was selected to demonstrate how a student presents their knowledge in the concept map. Both the student's pre- and post-concept maps on the concept of "Forecasting with Respect to Power System Operations" are provided in Figures 1 & 2. In reference to the rubric that was implemented in the analysis, there are distinct differences across the maps with respect to each of the rubrics three categories:

- *Comprehensiveness.* In the pre-map the use of language such as "used by" or "serves to" gives a general sense that the student may know some basic applications of Forecasting which could be acceptable for a novice student who has not yet engaged with this concept. In the post-map the language linking sub-concepts evolves into more detailed terms including "considers", "can be performed using" and "made up of" in addition to some of the language used in the pre-concept map.
- *Organization.* Both maps appear to be well organized in how they connect the main concept to multiple sub-concepts using specific linking terms. In the pre-concept map, most of the

connections seem to be linear in nature. However, while the connections are not presented as feedback loops the number of connections has significantly increased and are represented in a much more sophisticated series of structures.

- *Correctness.* Each of the evaluators who are experts in this area of research evaluated these novice students on the correctness in their conceptualization of the central concept. Initially both experts scored the participant with a 2.5 in the pre-concept map and then a 3 or max score in their post-concept map indicating that the students were initially fairly accurate and moved to wholly accurate in terms of their level of presented knowledge.

Table 3. Average Scores on Spring 22 Pre and Post Concept Maps

ID #	Pre-Concept Map Scores		Post-Concept Map Scores	
	Average Score	*Stnd. Dev.*	*Average Score*	*Stnd. Dev.*
1	7	0.71	8	0.71
2	5	1.41	8	0.71
3	7	0.71	Invalid	Invalid
4	5.25	0.35	7.5	0
5	7	1.41	7.5	1.06
6	7.5	1.41	6.5	0.71
7	5.25	0.35	8	0.71
8	7.5	1.41	7.5	0.35
9	5	0	-	-
10	7	0.71	-	-
11	5.25	0.35	-	-
12	5	1.41	-	-
13	7.25	0.35	-	-
Average Total	**6.23**	**0.82**	**7.57**	**0.61**

V. Future Work

As a work in progress, this paper shows the first round of assessment based on modifications made within a specific power and energy course. As is the goal of the overall project, continuous improvement and development of all of the courses in the project will continue based on the results of each assessment. This initial evaluation of the concept maps based solely on the rubrics provides an encouraging initial assessment of the work that has been done. Plans are being developed for ways to further analyze the concept maps to identify the frequency of specific terms, the number of connections made, and any apparent gaps across each map as additional data points to consider. The researchers continue to make improvements to these newly developed modules to continue to improve the results. Additionally, the research team is making plans to hopefully enhance participation throughout the data collection process to have consistent data points and a larger sample to analyze.

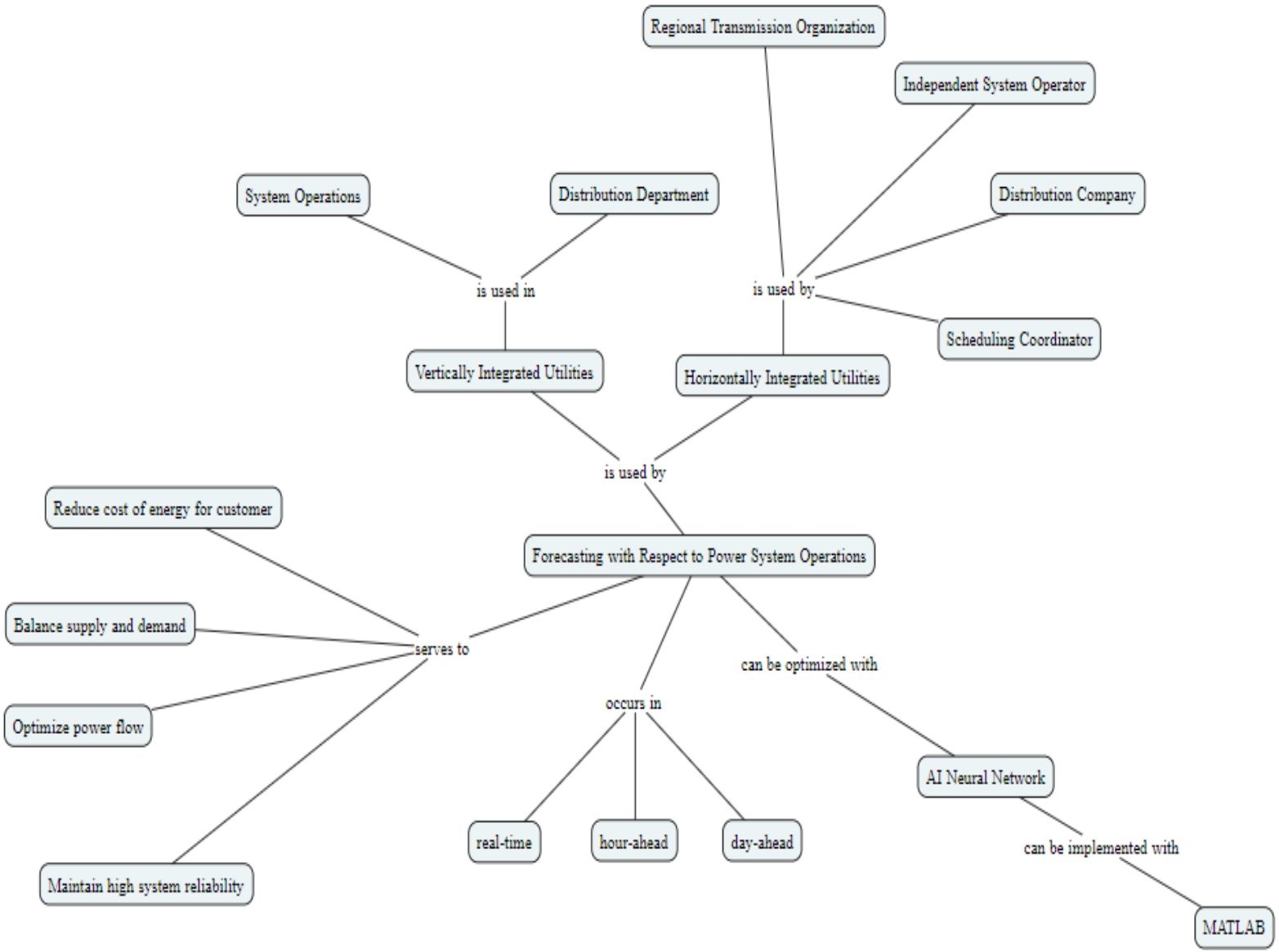

Figure 1. Concept Map Pre-Assessment of Forecasting with Respect to Power System Operations

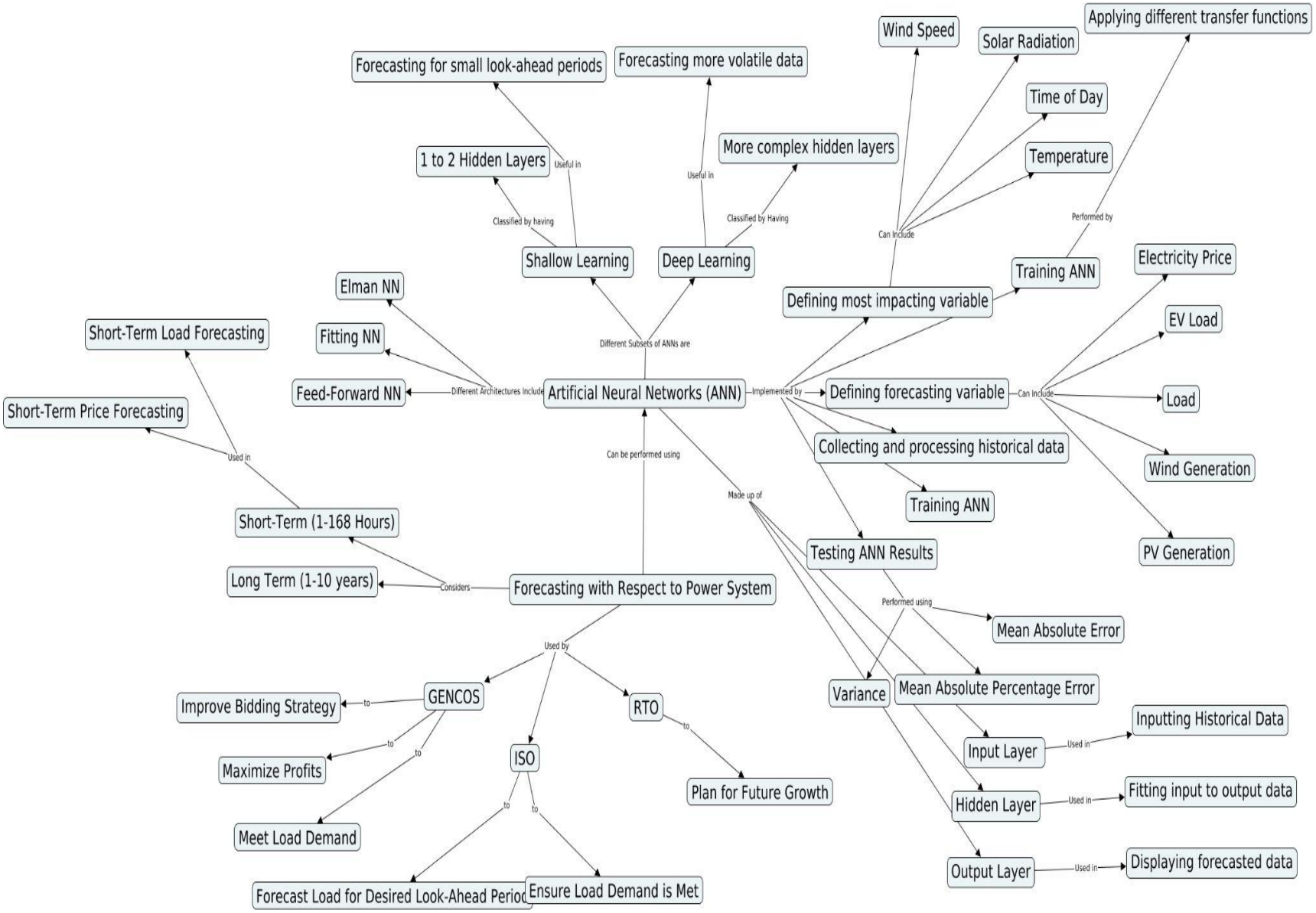

Figure 2. Concept Map Post-Assessment of Forecasting with Respect to Power System Operations

VI. Acknowledgement

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References

[1] Besterfield-Sacre, Mary, Jessica Gerchak, MaryRose Lyons, Larry J. Shuman, and Harvey Wolfe. 2004. Scoring Concept Maps: An Integrated Rubric for Assessing Engineering Education. Journal of Engineering Education 93 (2):105–115.

[2] Bodnar, Cheryl A, Hixson, Cory 2018. Capturing Students' Perception of Entrepreneurial Mindset: Tools for What and Why

[3] V. Cecchi, C. Smith-Orr, F. Atchison, S. Kamalasadan, P. Mandal and I. Lopez, "Assessing Student Perceptions of Emerging Concepts in Power & Energy Systems via Concept Maps: Rubric Development," 2021 IEEE Frontiers in Education Conference (FIE), Lincoln, NE, USA, 2021, pp. 1-4