

Using A Modular Framework for Assessing Professional Skills

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Abstract— More and more executives are now listing professional skills along with technical ones among their expectations from information Sciences and Technology and Engineering graduates. In fact, the lack of professional skills in project teams has been identified as one of the top contributors to the high failure rate of complex engineering projects. As a response, academic programs have incorporated professional skills in their curricula, which led to the challenge of assessing the relevant student development appropriately. This paper proposes using a Model of Domain Learning (MDL) assessment framework for this challenge. Moreover, the advantages of using this framework over the existing assessment tools are discussed. An empirical study, which assesses the teamwork communication skills, is also presented to demonstrate the practicality and effectiveness of the proposed framework.

Index Terms— Assessment of Professional Skills, Model of Domain Learning, Teamwork Communication.

I. INTRODUCTION

Professional skills are valuable attributes required by technical disciplines to complement technical skills in the practice of the profession [1]. The Accreditation Board of Engineering and Technology (ABET) defines students outcomes under its Criterion 3, which are specifically related to professional skills. These outcomes can be grouped into (i) process skills (i.e., communication, teamwork, and the ability to recognize and resolve ethical dilemmas), and (ii) awareness skills (i.e., understanding the impact of global and social factors, knowledge of contemporary issues, and the ability to do lifelong learning) [2].

The academia is expending significant efforts to enhance the curricula to promote the development of technical and professional skills in graduates of technical disciplines; however, the absence of robust assessment frameworks constrains the effectiveness of such efforts. The broader student outcomes are calling for effective mechanisms to evaluate not only technical but also professional skills across the curriculum. One of the main challenges is that existing assessment instruments were developed using different frameworks or models, making them difficult to integrate into an overall assessment of student outcomes. Whereas acquisition of professional skills in our graduates is

increasingly crucial due to global competition and intensifying pressures on companies (i.e., companies have fewer resources and less time to train employees on these skills), the absence of a robust assessment framework inhibits the propagation of pedagogical initiatives.

Beard et al. [3] suggest that an assessment plan to evaluate curricular efforts that aim to integrate professional skills into programs should include standardized rubrics for targeted courses in addition to comprehensive exit surveys, internship assessments, and student self-assessments. In this paper herein, it is argued that if assessment tools for professional skills are designed and assessment data are analyzed based on the same theoretical framework, deeper insights can be gained on why students perform in certain ways. With this thought, an assessment framework is presented, built upon the foundation of Alexander's Model of Domain Learning (MDL) [4].

The objective of the paper is to demonstrate how a theoretical learning model (i.e., MDL) can be utilized in order to gain better insights about students' professional skills development using an empirical study from the teamwork communication domain. The MDL is selected as the theoretical framework for an assessment model because of its demonstrated validity in predicting the stages of student development. Previously, the MDL has been tested in many different technical domains (e.g., [4-6]) and only recently it has been proposed to be used in the assessment of professional skills [7-9].

This paper is organized into four sections. First, a summary of current assessment techniques for teamwork skills, and a brief overview of MDL are given. Then, the proposed assessment framework is explained. An empirical study is presented to demonstrate the preliminary evidence on the appropriateness of the MDL as an assessment framework. Finally, MDL's advantages are discussed, and conclusions are provided.

II. LITERATURE REVIEW

A. Current State-of-the art on the Assessment of Teamwork

The global economy requires new graduates not only to attain technical disciplinary knowledge but also professional skills to maintain competitiveness in the global markets. The need for

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these skills is documented in the literature [2, 10]. Accordingly, academic institutions are making efforts to incorporate professional skills in their curricula and learning experiences to define, teach, and assess them (e.g., [1, 2]).

However, a major challenge is the assessment of professional skill development. Contrary to the technical skills in a particular discipline that are acquired and assessed directly, professional skills develop progressively throughout one's education and beyond [4, 11, 12], and hence are more challenging to assess. In some instances, it is also difficult to establish which skills are personality characteristics of individuals, and which ones can be developed through education. Other challenges might arise depending on the specific professional skill under consideration. For example, in the case of teamwork, the fact that individual contribution to the team might not be solely accounted for, or the grades of good students in a team might be affected by poor contribution of other team members, are major concerns for students and instructors [13]. Additionally, the tendency of individuals to work less as part of a team in comparison with what they would do individually might be a significant deterrent for implementing teamwork, and thus loss of its potential pedagogical benefits.

Generally speaking, the literature about teamwork assessment on skills, knowledge and ability (KSA) can be organized into two main groups: (i) studies on KSA taxonomy development [14-19], and (ii) studies of individual contributions to the overall team efforts [20-29]. The first group focuses on the studies of cognitive, affective and psychomotor domains of KSA while the second group is interested in measuring contributions of each team member and teamwork process to determine their impact in the overall performance of the team.

In technical disciplines such as engineering and information technology, a literature review shows that students' projects and teamwork evaluations are commonly used for assessment of professional skills [20-26]. The aim of this approach is to complete a summative evaluation of teamwork projects by considering: (a) individual behavior of each member within the team; (b) individual contribution of each team member to the project; (c) project process within the team; and (d) project outcomes. Some online tools such as SPARK [30] and CATME [16] have been developed to manage self- and peer- evaluations to determine individual behaviors, and contributions of team members in a project.

Based on the literature review aforementioned, assessment tools and rubrics can be found for assessment of teamwork skills; however, the existing instruments are limited to a single professional skill, and are related to specific courses or learning activities. There is a need for more research on the integration of learning models in support of students' development of professional skills longitudinally.

B. Model of Domain Learning

The Model of Domain Learning (MDL) is a learning theory where important constructs with potential effects on learning (e.g., interest in the domain that is studied) are included in addition to the sole consideration of learning in the cognitive

sense. Due to its inclusion of such important constructs to an assessment framework, the MDL provides a more comprehensive view of the learner as he/she engages in learning. For example, interest level is one such construct. Experimentations conducted by Alexander et al. [31] show that there are complex interactions between knowledge, interest level, and strategic processing with which expertise is gained. Alexander and her colleagues explain that in some cases learner performance is found to have a more significant causal link with interest in the particular domain than in learner's ability to acquire essential knowledge from text. Murphy and Alexander [32] confirmed the causal links of knowledge, strategic processing and interest on learning for the domain of educational psychology. Indeed, such empirical studies give way to the frameworks of expertise development that are non-traditional in that they go beyond solely cognitive and aim at developing expertise across stages (i.e., continuum) versus merely duplicating the expert performance; the MDL is one example of this.

Significant factors with potential impact on learning in a domain or field of study are described by the MDL proposed by Alexander [5]. A domain encompasses the knowledge, skills and attitudes that need to be taught specifically. Within the MDL, three experience-based stages occur (i.e., acclimation, competency and proficiency), which are progressive and incremental. Table I summarizes the possible state of three components (knowledge, strategic processing, and interest) over the three stages. Once a learner has progressed to a more advanced stage, it is considered unlikely that he/she will return to an earlier stage of development.

At the first level of the proposed assessment framework, the master rubrics are organized in areas of learning outcomes. In the second level, each learning outcome area includes several core competencies/attitudes expected from students, and these competencies/attitudes are operationalized by measurable rubric items. The rationale and learning outcomes for professional skills are well-defined in the literature, and many institutions have incorporated them into their program goals and objectives as required by the accreditation boards (i.e., ABET). In the final level, these rubric items are also organized and reformulated in terms of the MDL components (i.e., knowledge, interest, strategic processing) and mapped on the three stages of the MDL (i.e., acclimation, competency, and proficiency) as seen in Table I. This mapping process is a critical contribution of the proposed framework.

The MDL is different and more advantageous from stage theories of learning due to its proposal that three primary factors (knowledge, interest and strategic processing) interact with the three stages of learning [33]. Over time, for example, reliance on domain-general strategies gives way to more powerful domain-specific strategies; interest shifts from situational to individual; and powerful, principle-driven domain knowledge supports learning and problem solving. In the MDL, evidence of development is obtained when students show shifts along the three dimensions toward expertise; therefore, MDL lends itself to longitudinal measurement. Due to the above-mentioned benefits, the MDL is chosen as our theoretical framework.

Although the MDL is a generalized model of expertise in that it proposes that the three stages of development (acclimation, competency and proficiency) occur for any academic domain, it is also domain specific. During the past two decades, Alexander and her colleagues have investigated the MDL and its predicted relations among knowledge, interest, and strategic processing for those moving toward expertise in domains of social studies, astrophysics, human biology/immunology, educational psychology, and special education, involving students from elementary through graduate school [4, 6, 31, 32]. Others have conducted studies of the MDL in such domains as history, technology, music therapy, physical education [33-36]. These studies using both quantitative and qualitative methodologies, as well as cross-sectional and longitudinal designs, have upheld model predictions, and thus support the selection of the MDL for the proposed cross-disciplinary professional skill assessment. Despite the wide array of domains in which the applicability of MDL has been tested, we have not found studies that focused on the domain of Information Sciences or Engineering, specifically in the development of professional skills. Thus, the work presented here not only contributes to the empirical studies of MDL but also introduces a new framework for the assessment of professional skill development.

TABLE I
MDL COMPONENTS AND STAGES

| | Acclimation | Competency | Proficiency |
|-----------------------------|-------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Interest | <u>Situational interest:</u> Spontaneous, transitory, and environmentally activated interest | Increased individual interest due to increased engagement in a domain | <u>Individual interest:</u> long-term, deepening, personal connection to a domain, which in turn inspires further exploration of the domain |
| Knowledge | <u>Limited and fragmented knowledge</u> | More cohesive domain knowledge | <u>Broad and deep knowledge</u> |
| Strategic Processing | <u>Surface-level strategies:</u> The implicit acceptance of information | A mixture of surface-level and deep processing strategies | <u>Deep processing strategies:</u> Applying isolated knowledge in problem solving procedures |

III. PROPOSED ASSESSMENT FRAMEWORK

In the proposed framework, the learning outcomes are catalogued into a master rubric for each targeted professional skill. The master rubrics are envisioned to be designed in a modular fashion. By categorizing each master rubric item using the MDL, the aim of this work is to provide educators a platform with which assessment data from various sources can be compiled, analyzed and compared in a standardized way. In the following section, how this mapping can be used to gain insights about students' development in professional skills (using an example from teamwork communication), is demonstrated. More specifically, it is attempted to provide preliminary evidence, using teamwork communication as a

sample professional skill, and to respond to the following research questions:

- i. Do students improve their professional skills over time? What is the MDL stage that students reach?
- ii. What are the advantages of analyzing assessment data based on the MDL framework?

IV. AN EMPIRICAL STUDY

In this section, an empirical study to demonstrate the advantages of the MDL-based assessment framework using the domain of teamwork communications as the targeted professional skill is presented.

A. Data Collection Instrument

Multiple-choice questions adapted from the Teamwork Knowledge, Skills, and Abilities (KSA) Test [14, 15] are used to measure students teamwork knowledge and strategic processing abilities. The Teamwork-KSA Test does not specify the learning outcome areas for the test items. Therefore, first, the test items were reviewed to identify a subset that relates to teamwork communications. Next, the test items were categorized into three MDL stages (i.e., acclimation, competency, and proficiency), and into two of the MDL components as knowledge and strategic processing. At the acclimation stage, the knowledge questions measured students' basic knowledge in the teamwork communications domain and their ability to differentiate between the accurate and inaccurate information. At the competency stage, the knowledge questions required more in-depth knowledge. For these knowledge questions, students were required to integrate multiple pieces of information to correctly answer them. The knowledge questions at the proficiency level included highly structured information about teamwork communications. To answer the proficiency level questions correctly, students should have not been enticed by the choices that seemed obvious. It is anticipated that the majority of the participants in this empirical study would find proficiency level questions difficult since they were not expected to reach the proficiency level. The strategic processing questions involved problem solving skills and the application of the teamwork domain knowledge into real-life scenarios.

It is important to reiterate that the categorization of the questions was performed prior to the administration of the data collection instrument depending on the collective judgment and expertise of the research team. In practical applications of an assessment instrument based on the MDL framework, the categorization of assessment items may be updated based on the data collected over time. However, because the objective of this study is to demonstrate the use and advantages of the proposed MDL-based assessment framework and to answer our research questions, *a priori* and appropriate categorization of the survey items was necessary. As it will be discussed in detail in the following section, the results support the appropriateness of categorizing the questions into the acclimation, competency, and proficiency stages. In both knowledge and strategic processing components, the average score decreased significantly from the acclimation stage to the proficiency stage

as expected.

The third component of the MDL is interest. In addition to the knowledge and strategic processing questions, the instrument included Likert-scale questions to measure students' interest (at the individual level) in the domain of teamwork communications. The MDL considers two types of interest: situational and inherent. Situational interest is the temporary interest that arises spontaneously due to external factors, such as a new topic or an engaging text. On the other hand, inherent interest is the long lasting interest that motivates students to gain deeper knowledge in a domain. Inherent interest is an indicator of how much students are willing to immerse themselves into a domain. According to the MDL, an increased inherent interest in a domain is a result of higher knowledge and strategic processing abilities in that domain. It is also a precursor for sustaining long-term learning. Therefore, evaluating students' inherent interest is especially critical for professional skills assessment, where sustainable, long-term learning is paramount. In this study, participants' inherent interests were measured using the three Likert-scale questions (five levels ranging from 1-Not Interested to 5-Very Interested) as given below. These questions had a reliability of 0.68 (internal consistency Cronbach's Alpha Value).

- *Considering your previous teamwork experiences and how effective communication could have improved team performance, please rate your level of interest in attending a free workshop on teamwork communication skills.*
- *How likely will you be interested in reading a book/article not so exciting but useful about teamwork communication?*
- *A renowned communication guru will give a workshop on teamwork communication skills. If you have to pay to attend the event, please rate your level of interest in attending this workshop.*

Students were asked to rate the importance of teamwork communication skills for their intended professional career using a five-point scale with extreme points: 1-Not at all important, 5-Very Important. In addition, the following two Likert-scale questions (five levels ranging from 1-Not at all confident to 5-Very confident) were used to measure students' self-efficacy about teamwork communication (internal consistency Cronbach's Alpha Value of 0.65).

- *Please indicate how knowledgeable you are about skills and attitudes for effective team communication.*
- *Please indicate how confident you are about your communication skills in teamwork.*

B. Participants and Methods

In this empirical study, there were 198 participants from Engineering (109), Information Sciences and Technology (IST) (89) programs at a land-grant university in the Northeast region of United States. All participants were undergraduate students. They were in various stages of their undergraduate degree programs: freshman (49), sophomore (61), junior (30), and senior (58). Collected responses were analyzed in two groups:

freshman/sophomore- Group I (110) and junior/ senior- Group II (88). Participants took the survey during class time, and they were informed that their performance would not affect their course grade, but the survey results would be used to improve the current curriculum; all participants chose to respond to the survey. Analyzing the data in two groups was preferred instead of four separate groups because the development of professional skills is expected to be gradual. A *t*-test was conducted to measure the significance of the differences between these groups.

V. RESULTS AND DISCUSSIONS

Table II summarizes the average overall assessment scores, the average scores of domain knowledge and strategic processing questions, as well as the average scores of inherent interest, perceived importance, and self-efficacy questions for the two groups. In the overall scores, Group II performed about 5% higher than Group I did (with a statistical significance of $p=0.011$). The overall test score in Table II indicated a slight progress in teamwork communication skills of students, but these scores cannot provide any feedback on why students perform in certain ways or provide guidance on how the curricular content might be improved to increase skill acquisition. Nonetheless, the aggregated results in Table II provide preliminary evidence supporting that professional skill development of students can be tracked throughout their educational journey, which can be observed by the significant increase in professional skills of Group II students. Although this empirical study does not involve multiple assessments of the same student over time, the sample size is large enough to account for learner-based variations.

TABLE II
AVERAGE ASSESSMENT SCORES

| | Group I | Group II | <i>p</i> -value |
|----------------------|---------|----------|-----------------|
| Overall Test Score | 48.4% | 53.5% | 0.011 |
| Knowledge | 49.1% | 50.2% | 0.594 |
| Strategic Processing | 33.3% | 40.2% | 0.060 |
| Self-Efficacy | 3.9 | 4.1 | 0.062 |
| Interest | 2.3 | 2.4 | 0.602 |
| Perceived Importance | 4.6 | 4.7 | 0.376 |

The overall result given in Table II could be generated using any assessment rubric or test and does not necessarily reflect the advantages of the MDL-based assessment framework. The advantages of the MDL-based assessment framework become apparent when the overall test score is broken down into the MDL components, knowledge and strategic processing. As seen in Table II, the improvement in the overall test score from Group I to Group II was mainly due to the strategic processing component while the two groups scored virtually identical in the knowledge component. This result indicated that Group II did not gain significant knowledge in the domain of teamwork communications, but they were still able to solve problems as a result of their increased strategic processing abilities through their educational journey. This result should raise a flag for the

effectiveness of curricular and extra-curricular programs to promote teamwork skills, and trigger effectiveness evaluation and further improvement of the curriculum.

Another concern is the low level of interest. Participants overwhelmingly indicated that teamwork communications skills were important for their majors and career goals, but they indicated little interest and motivation for participating in professional activities to advance their skills in this domain. Gaining expertise in a domain might be traced by the correlations of the knowledge, strategic processing and interest scales according to the MDL theory. One of the advantages of the proposed MDL-based assessment framework is to allow instructors to make inferences about student progress based on the MDL theory. In the empirical study, two groups of students rated their interest level almost identical. As seen in the correlations given in Table III, the overall, knowledge, strategic processing scores were not correlated with the individual interest scores. In this study, the individual interest construct is intended particularly to measure how much students are willing to exert personal effort in learning teamwork communication skills. In light of the MDL framework, the lack of correlation between the knowledge and the individual interest constructs as well as the lack of a significant increase in the individual interest levels of students from their first two years to their last two years indicate that the transformation of students from acclimation toward competency in the domain of teamwork communications has not been completed. On the other hand, if the student progress was analyzed based on the overall score only, evaluators could be satisfied with the scores presented in Table II because the comparison of the overall test scores between the two groups suggested progress. In other words, aggregated scores mask the relationships among knowledge, interest, and strategic processing.

TABLE III
CORRELATIONS AMONG THE MDL COMPONENTS

| | Overall | Knowledge | Strategic Processing | Interest |
|----------------------|---------|-----------|----------------------|----------|
| Overall | 1 | 0.651* | 0.672* | -0.061 |
| Knowledge | 0.651* | 1 | .090 | -0.012 |
| Strategic Processing | 0.672* | -0.012 | 1 | -0.038 |
| Interest | -.061 | -0.012 | -0.038 | 1 |

*: Correlation is significant at the 0.05 level (2-tailed).

In the proposed framework, it is possible to evaluate assessment outcomes against a theory that explains the journey of students toward expertise in a domain and to make more informed judgments about where students are in their educational journey. Score-based rubrics are based on expected competencies and attributes from students, but they may fail to analyze the relationships between those competencies and attitudes. In this sense, the proposed MDL based framework provides a deeper insight without solely depending on the average assessment scores.

The question about how the MDL assessment can be used to evaluate students' progress toward proficiency has not been answered yet. When student scores were analyzed with respect

to the MDL stages as seen in Table IV, students had low scores in the competency and proficiency level questions, which required more in-depth knowledge and the integration of several pieces of information. Students' perceptions of the importance of teamwork communication skills were high in both groups as seen in Table II, but they were not ready yet to commit individual effort for the mastery of those skills as indicated by the low interest scores. In light of the MDL framework, therefore, it could be concluded that students are still at the acclimation stage based on the empirical results presented in this paper.

By analyzing the data in knowledge, strategic processing, and interest, the proposed MDL based assessment can point out deficiencies in students' progress toward achieving competency as is done for the presented case. This is the main advantage of the proposed MDL-based assessment framework over traditional score-based assessments.

TABLE IV
AVERAGE ASSESSMENT SCORES

| | Group I | Group II | p-value |
|----------------------------------|---------|----------|---------|
| Knowledge Acclimation | 64.3% | 59.1% | 0.084 |
| Knowledge Competency | 53.0% | 54.5% | 0.704 |
| Knowledge Proficiency | 25.6% | 32.9% | 0.019 |
| Strategic Processing Acclimation | 49.5% | 58.5% | 0.068 |
| Strategic Processing Competency | 39.7% | 42.0% | 0.616 |
| Strategic Processing Proficiency | 16.0% | 26.1% | 0.006 |

Another advantage of the proposed MDL-based framework is that the MDL theory is independent from the domain. The proposed framework provides a uniform assessment model for designing assessment plans to evaluate the effectiveness of curricular efforts that aim to integrate various professional skills into different programs. Being able to compare assessment data from various areas on a uniform framework may better inform educators about what is lacking and how to improve the curricula content and strategies attempting to improve students' professional skills in those areas. In the empirical case presented in this paper, for example, with no difference in domain knowledge at the acclimation and the competency levels as seen in Tables II and IV, the observed difference in the proficiency level could be attributed to an increase in students' strategic processing abilities. A real improvement in students' domain knowledge should be observed at the competency stage as well. Therefore, the progress that was observed in the domain knowledge at the proficiency stage could be attributed to the improvement of the participants in understanding and responding to questions (i.e., strategic processing abilities). Group II students were able to perform better at the proficiency stage because their strategic processing abilities improved, but not necessarily their domain knowledge. The lack of relationship between the interest and domain knowledge also supports this claim. The analysis of the test scores based on the MDL framework suggests that students are at the acclimation or early competency stages in terms of their teamwork communication skills.

VI. CONCLUSIONS

This paper presented the assessment challenges in students' development in their professional skills, and subsequently proposed the use of an MDL-based assessment framework. Among the unique advantages of the proposed framework are: *i*) the MDL-based assessment can track professional skills development over time, *ii*) assessment comparisons are inherently rich pointing to student interest, knowledge and strategic processing, and *iii*) this assessment approach allows determining learning progress at different stages, and thereby providing feedback for early intervention and/or curriculum adjustments to reach the desired learning outcomes and competencies. The overall goal of this work was to show the application of MDL as the core of a modular assessment system for professional skill attainment. With the included empirical study with 198 participants (i.e., Engineering and Information Sciences and Technology undergraduate students), we have demonstrated how the MDL-based assessment framework can be used for the teamwork communication skill attainment. Future studies will focus on assessing other professional skills.

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