

# A Framework for Soft Skills Training in Science and Engineering

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## ABSTRACT

Ask the graduates and the employers of graduates of computing information sciences and engineering (CISE) one area in which more formal training would have been beneficial while still in college. It is not surprising that both the employers and the graduates often agree that students require more training in discipline-specific soft skills (DSSS) in CISE. Yet, the requirements for undergraduate DSSS in CISE remain an open subject for debate. Should all undergraduate core courses be revised to incorporate DSSS requirements? Should DSSS be designed for infusion into the technical core courses for undergraduates in CISE? How should student learning outcomes (SLOs) for DSSS be defined and assessed? This paper discusses these and further questions.

### Categories and Subject Descriptors

k.3.2 [Computers and Education]: Computer and Information Science Education –*computer science education, curriculum.*

**General Terms:** Design

**Keywords:** Student learning outcome, IT soft skills, soft skill activities, soft skill assessment.

## 1. INTRODUCTION

Computer Science and Information Technology (CSIT) departments are periodically required to conduct internal and external program reviews to satisfy accreditation requirements [4]. Today, there are available resources for the philosophy of assessment [1], experiences gained from practical assessments [2], valuable pedagogy for student projects [3], and a step-by-step guide for assessments [6].

Student learning outcome assessment (SLOA) is the organized compilation of information about student learning for decision making on how to improve instruction and learning. Today, accrediting agencies require SLOA. Ideally, every major course in a degree program should have student learning outcomes (SLOs) that map into the program's SLOs. The systematic collection and processing of data about student learning from a variety of courses entail cumbersome processes. Fortunately, Olagunju et al. have developed a practical self-contained tool to facilitate meaningful graduate follow-up and curriculum assessment at course and program levels [5]. Unfortunately, SLOA for soft skills in CSIT is

still rare to find. This research focused on the design and implementation of a variety of team and individual activities and projects for infusing soft skills into the learning of the technical skills of the Information Technology Security (ITS) degree's core courses. However, the approach to the infusion of DSSS into the ITS degree program is easily adaptable to any program in CISE.

## 2. DSSS IMPLEMENTATION MODELS

Traditionally, individual faculty members include and assess soft skills in individual courses. Unfortunately, this approach to the infusion of soft skills into the core technical skills of courses makes it difficult to systematically collect and document the SLOs of DSSS of all students upon graduation. Ideally, DSSS ought to be phased into each degree program. This requires the operational definitions of all DSSS for a curriculum, a map of the DSSS to the core courses, and the specific activities and assessment of selected DSSS in each course. This comprehensive approach requires the buy-in from all faculty members involved in a degree program. This paper presents a framework for operationally defining DSSS, the activities and assessment of soft skills, and a generic tool to facilitate the assessment of DSSS in CISE. The framework is illustrated using the DSSS of the ITS degree program at St Cloud State University.

## 3. INFORMATION TECHNOLOGY DSSS

### 3.1 Core Courses

The ITS core courses at St Cloud State University are:

**CNA 201: Computer Networking Concepts** (Local Area Networks, LAN configuration and troubleshooting, client-server, networking, peer-to-peer networking).

**CNA 267: Beginning Programming** (Python programming in windows environment. Input and output of data, accumulators and counters, loops, functions and subroutines, one and two dimensional arrays, sequential files, random files).

**CNA 397: Operating Systems of Micros** (Binary and hex arithmetic, microcomputer architecture, data types, storage classes and operators, control structure, operating systems, functions and characteristics, concurrent processing, I/O, resource allocation and scheduling ).

**CNA 425: Computer Networking** (Network architecture, characteristics, and protocols, software packages, set up, theory, and use of local area networks; detail coverage and application of the physical layer of the TCP/IP model; simulation projects).

**CNA 426: Computer Networking II** (Data link through application layers of the OSI model).

**CNA 430: Firewall and Penetration Testing** (Network access control; firewall planning, installation, configuration, management, and performance; network intrusion detection and prevention).

**CNA 432: OSI Layers Security** (Security models and protocols for each OSI layer; network and Web security implementation, monitoring, intrusion, recovery, and countermeasures).

**CNA 436: World Wide Web Authoring and Administration** (Authoring and implementing web documents; setting up and administering web servers).

**CNA 473: Operational Software Safeguards** (Implementation of network security policy; evaluation of hacker tools; preventative measures; monitoring attacks and analyzing logs).

### 3.2 ITS SLOs

Students work individually and in groups, on specially-designed activities and projects with focuses on DSSS in the core courses to achieve the following SLOs defined for the ITS degree.

- Create, analyze, and modify security policy.
- Design and implement secure network architecture based on security policies.
- Exhibit knowledge of security laws and ethics.
- Identify and correct security weaknesses in operating systems, networks, and applications.
- Identify and respond appropriately to security breaches.
- Apply cryptography and other theoretical foundations of security to secure information and systems.
- Use security protocols at each layer of the TCP/IP model to form layered security architectures.

### 3.3 DSSS COMPETENCIES

The ITS core courses provide students DSSS competencies in:

- Project and process flows (research, analyze and synthesize, design and implement, test and validate, quality assurance and project management)
- Oral, written and workplace communication and teamwork
- Task management, professionalism and professional development
- Problem solving (data collection, analysis and organization; problem definition, solution development and testing)

Appendix A contains the map of the ITS courses used to assess the DSSS.

### 3.4 DSSS ASSESSMENT

In technology programs, assessing soft skills is difficult. These skills such as communication, problem solving and teamwork, are considered critical to success in industry, yet they are often underemphasized in IT programs as too difficult to assess. Perhaps in most courses, the students practiced these skills, but too often the students received little feedback on their performance and few suggestions on how to improve. This section contains a sample of the set of criteria and guidelines for assessing the performance of students in soft skills critical to the success of all IT security professionals.

The infusion of soft skills into IT security curriculum philosophy strongly supports the alignment between activities/projects and assessment of student learning. Combining assessments with projects that incorporate real and simulated work-like activities and situations significantly reinforces the learning process. For each soft skill, three levels of proficiency (basic, intermediate, advanced) with increasing skill performance and complexity are defined. These levels and associated criteria are validated for reliability. For each level, five criteria are defined as the expected performance for the specific level. Based on the specific courses, some criteria could receive more emphasis than others. The criteria can be used as tools to assess the assignments, projects and other work products of students and eventually be used to assign grades. However, the criteria are also effective tools to help students recognize the expected performance and quality indicators of the specific skills. Consequently, students could use the criteria for self-assessment of performance and to provide guidelines for endless improvement.

Herein are the criteria and suggestions for the assessment of soft skills in the context of an Information Technology Security core courses for “**4.1 Data Gathering, Analysis and Organization**” in Appendix A.

Using individual and group projects, the following assessment criteria can be used:

#### (a) Basic Data Gathering, Analysis and Organization Skills

- Sources of data are clearly identified and relevant to the problem
- Data is evaluated for validity, completeness and relevance
- Conflict between data is appropriately resolved
- Data is recorded accurately and organized efficiently
- Documentation of data follows standards and procedures

#### *Sample Activity*

Students are asked to gather data through direct observation and research, to analyze and document this data in a usable format.

#### (b) Intermediate Data Gathering, Analysis and Organization Skills

- Need for data is clearly and accurately specified, and appropriately justified
- The scope of data gathering and analysis is congruent with the purpose, and the availability of time and resources
- Student accurately judges when there is sufficient or insufficient data

- Analysis of data is conducted using appropriate logical and statistical methods
- Data analysis and summaries are organized and documented in appropriate formats

**Sample Activity**

Students are asked to analyze complex sets of data and develop effective summaries based on the purpose of the activity.

**(c)Advanced Data Gathering, Analysis and Organization Skills**

- Correlations and divergence within the data sets are identified and accurately interpreted
- Data gathering, analysis and organization process is evaluated for accuracy and effectiveness, and recommendations for improvement are made
- Analysis process is planned and designed to meet the specific purpose of the experiment
- Data is organized and displayed using sophisticated charting and display tools
- Errors and uncertainties in the data gathering process are clearly identified, and their impact on validity of data is clearly evaluated

**Sample Activity**

Students are asked to develop, test and apply data gathering, analysis and organization processes, and to evaluate their effectiveness in the context of the activity.

In the CNA 432 course, one activity and a method of assessing individual students on security risk assessment for “**4.1 Data Gathering, Analysis and Organization**” is as follows.

**ACTIVITY DESCRIPTION**

In 2005, the Genomic Computation Lab (GCL) at an endowed university received \$500,000 grant to purchase 25 servers dedicated to Artificial Intelligence research on the determination of the functionalities of gene structures. All servers were supposed to be secured with padlocks. Unfortunately, two servers were stolen one year later from the GCL in 2006.

(a) What was the Exposure Factor for the theft of a server in 2006? Explain all assumptions. [3 points]

The Federal Bureau of Investigation (FBI) was asked to look into the theft of the two servers in 2007. The FBI recovered the two stolen servers from a technician who worked at the GCL in 2006.

(b) What was the Exposure Factor of a stolen server in 2006? Why? [3 points]

(c) Explain the discrepancies (if any) between the responses to (a) and (b) above. What might have happened? [4 points]

**SCORING/ASSESSMENT RUBRIC**

- 0-3 = [No achievement, level 0]
- 4-5 = [Basic achievement, Level 1]
- 6-8 = [Intermediate achievement, Level 2]
- 9-10 = [Advanced, Level 3]

For each CNA course listed in Appendix A, the faculty members provide the descriptions of the activities and assessment data for the DSSS. Specifically, each faculty member assigns numbers to students and provide the level of achievement of each skill (No achievement = 0, Basic = 1, Intermediate = 2, Advanced = 3) for each student.

**4. SSAS FEATURES**

Soft Skills Assessment System (SSAS) is an integrated generic data management system that supports the assessment of soft skills in a variety of IT courses. SSAS is a relational data management system with separate interfaces for its administration and course instructors. Appendix B shows the schematic view of the interacting program modules of the SSAS.

For all IT courses, SSAS offers features for an administrator to:

- Create a file of soft skills list (enter, update and delete a skill)
- Record the assessment rubrics for each skill (enter, update and delete a rubric)
- View each soft skill and associated rubric; view all soft skills and rubrics.
- Merge a set of soft skills files submitted by instructors into MSSFile.
- Use MSSFile to generate the progress report of each student across courses.
- Use MSSFile to generate the progress report of all students across courses using graphical displays and descriptive statistics.

Appendix C is a snapshot of the interface of the course administration.

For each course, SSAS offers features for an instructor to:

- Create a course file, and enroll students (enter, update and delete a record)
- View the Soft Skills List and select specific skills to be assessed in the course
- Record the activities for assessing each soft skill (enter, update, delete a record)
- Record the grades of students for each activity of a soft skill (enter, update, delete a record)
- View tabulated results of assessed soft skills for each student, and for all students
- Provide summaries (graphical displays and descriptive statistics) for each soft skill using all students’ data

Appendix D contains the snapshots of the interfaces an instructor uses to administer the DSSS of courses.

**5. CONCLUSIONS**

The ITS faculty members at St Cloud State University have implemented the framework for infusing DSSS into the ITS degree program. To date, we have a rich databank of the areas in which students are deficient in DSSS. We continue to fine-tune the individual and team activities for assessing DSSS. Prior to

implementing the DSSS, less than thirty percent of our graduates could be certified as proficient in soft skills. Today, the percentage of our graduating seniors who achieve at least “intermediate” proficiency in soft skills is over sixty percent.

The implementation of the framework for infusing DSSS into degree programs is not without problems. It is difficult to engage faculty members who are overburdened with teaching in new research. Providing graduate assistants or additional compensation should help overcome this issue. The design of creative individual and group activities and projects that promote the incorporation of DSSS into teaching is not easy. Faculty members ought to seek assistance from industry partners to overcome this problem. Changing the culture of learning by students to include DSSS sometime faces resistance. The new expectations of DSSS by employers should be clearly shared with all students in a degree program.

## 6. REFERENCES

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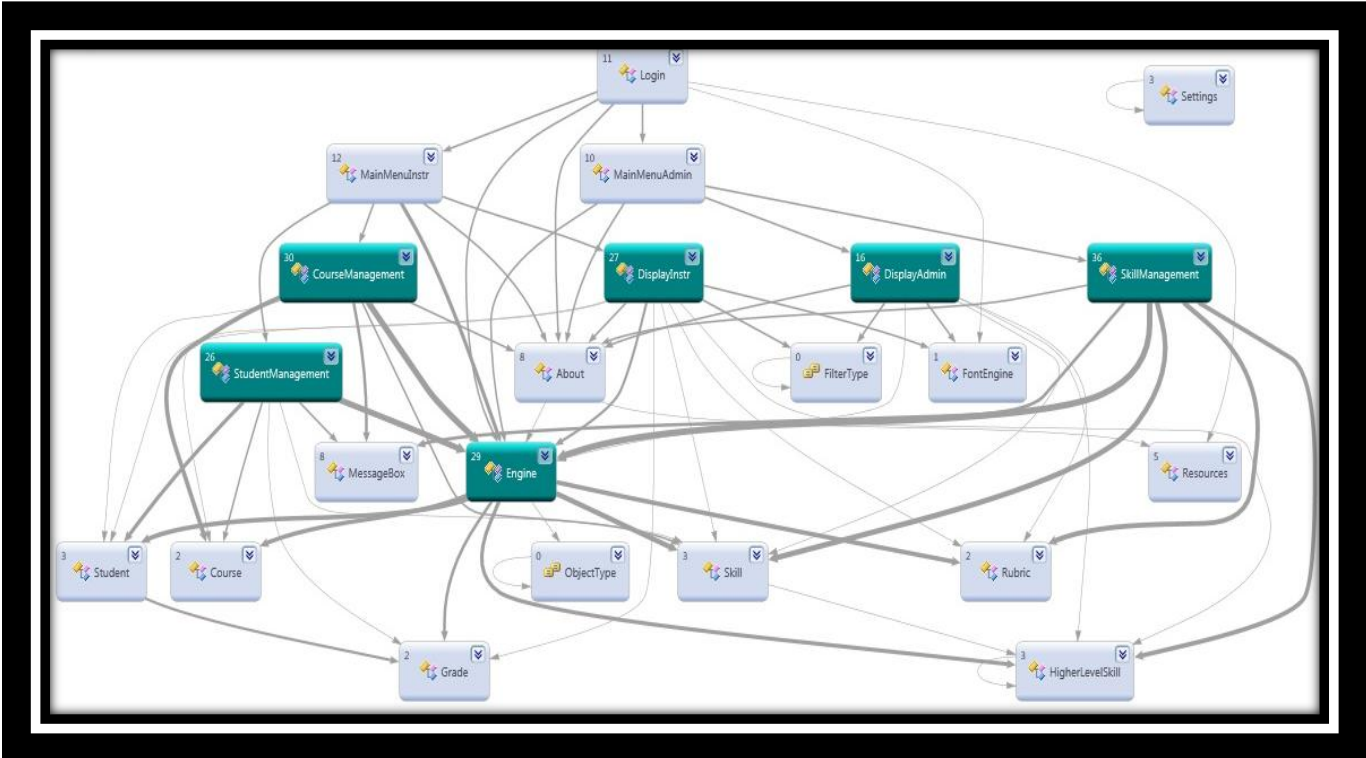
## APPENDIX A: ITS Soft-Skills and Courses Map

### SOFT SKILLS

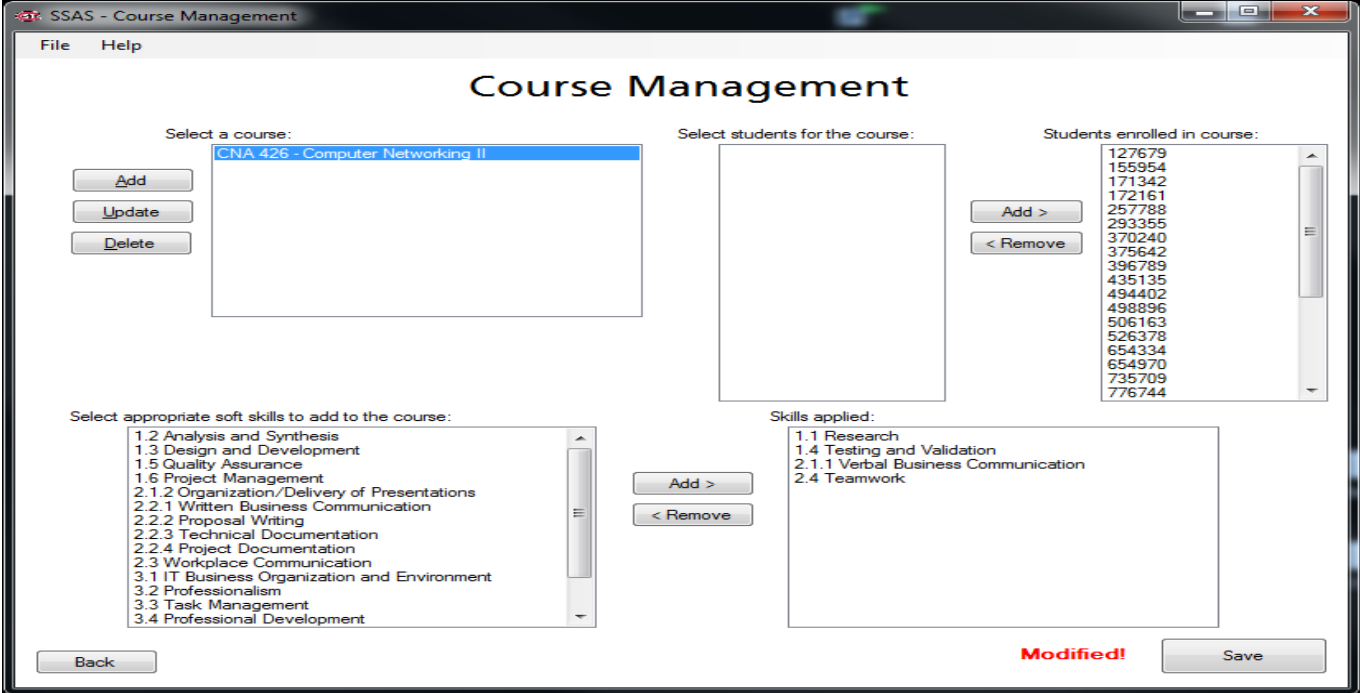
### CNA COURSES

	201	267	397	425	426	430	432	436	473
<b>1. Project and Process Flow Skills</b>									
1.1 Research			X	X	X		X	X	X
1.2 Analysis and Synthesis	X			X			X		
1.3 Design and Development	X	X				X	X	X	
1.4 Testing and Validation		X					X	X	
1.5 Quality Assurance									X
1.6 Project Management									X
<b>2. Communication and Coordination Skills</b>									
2.1 Oral Communication									
2.1.1 Verbal Business Communication								X	X
2.1.2 Organization/Delivery of Presentations				X	X	X	X	X	
2.2 Written Communication									
2.2.1 Written Business Communication							X		X
2.2.2 Proposal Writing							X	X	X
2.2.3 Technical Documentation	X		X	X		X	X	X	
2.2.4 Project Documentation		X					X	X	
2.3 Workplace Communication									X
2.4 Teamwork	X			X	X	X	X		X
<b>3. IT Business Environment Skills</b>									
3.1 IT Business Organization & Environment									
3.2 Professionalism	X			X					X
3.2 Task Management	X			X			X		
3.3 Professional Development	X			X			X		X
<b>4. Problem Solving</b>									
4.1 Data Gathering, Analysis & Organization	X			X	X		X		
4.2 Problem Definition								X	
4.3 Solution Development and Testing	X			X				X	X

### APPENDIX B: Schematic View of the Interacting SSAS Program Modules



### APPENDIX C. Course Administration Interface



## APPENDIX D. Instructor's Course Administration Interfaces

SSAS - Student Management

File Help

### Student Management

Add or remove students from the program database:

Add Update Delete

- 127679 - 00631370
- 155954 - 10348782
- 171342 - 00640174
- 172161 - 00671131
- 257788 - 00577968
- 293355 - 00600013
- 370240 - 00589935
- 375642 - 00529521
- 396789 - 00417895
- 435135 - 00652412
- 494402 - 00620126
- 498896 - 00611003
- 506163 - 10204111
- 526378 - 00091073

Select a course:

CNA 426 - Computer Networking II

### Assessment

Select a skill:

- 0 - 1.1 Research - 2
- 14 - 2.4 Teamwork - 0\*
- 3 - 1.4 Testing and Validation - 3
- 6 - 2.1.1 Verbal Business Communication - 0\*

Select an appropriate grade:

3

No achievement = 0  
Basic = 1  
Intermediate = 2  
Advanced = 3  
Ungraded = 0\*

Modified!

Back Save

SSAS - Display Data

File Help

### Display Data

Select a filter:

Skills

View All Skills & Rubrics

All Skills

All Rubrics

Skills by Course

Aggregate Skills

Students

All Students Assessed

View Student Individually

Students Only

Students By Course

Courses

All Courses

View Course Individually

Back

SSAS - Skill Management

File Help

### Skill Management

Select a skill:

Add Update Delete

- 1.1 Research
- 1.2 Analysis and Synthesis
- 1.3 Design and Development
- 1.4 Testing and Validation
- 1.5 Quality Assurance
- 1.6 Project Management
- 2.1.1 Verbal Business Communication
- 2.1.2 Organization/Delivery of Presentations
- 2.2.1 Written Business Communication
- 2.2.2 Proposal Writing
- 2.2.3 Technical Documentation
- 2.2.4 Project Documentation

Select or add a rubric:

Add Update Delete

Rubric

Currently attached to higher level skill:

1. Project and Process Flow Skills

Select a higher level skill to attach to the skill:

Add

- 1. Project and Process Flow Skills
- 2. Communication and Coordination Skills
- 2.1 Oral Communication
- 2.2 Written Communication
- 3. Business Environment Skills
- 4. Problem Solving

Rubric Description:

**Activity and Assessment Descriptions:- Students were grouped together with no less than 4 and no more than 5 students per group. Each group was assigned a topic on which they would have to conduct research. Each group will have to present their findings in class in the form of a formal presentation, and write a report. The soft skill was assessed based on the technical detail and in-depth quality of their work.**

Modified!

Back Save