Leveraging Remote Online Education for SE Competency Development

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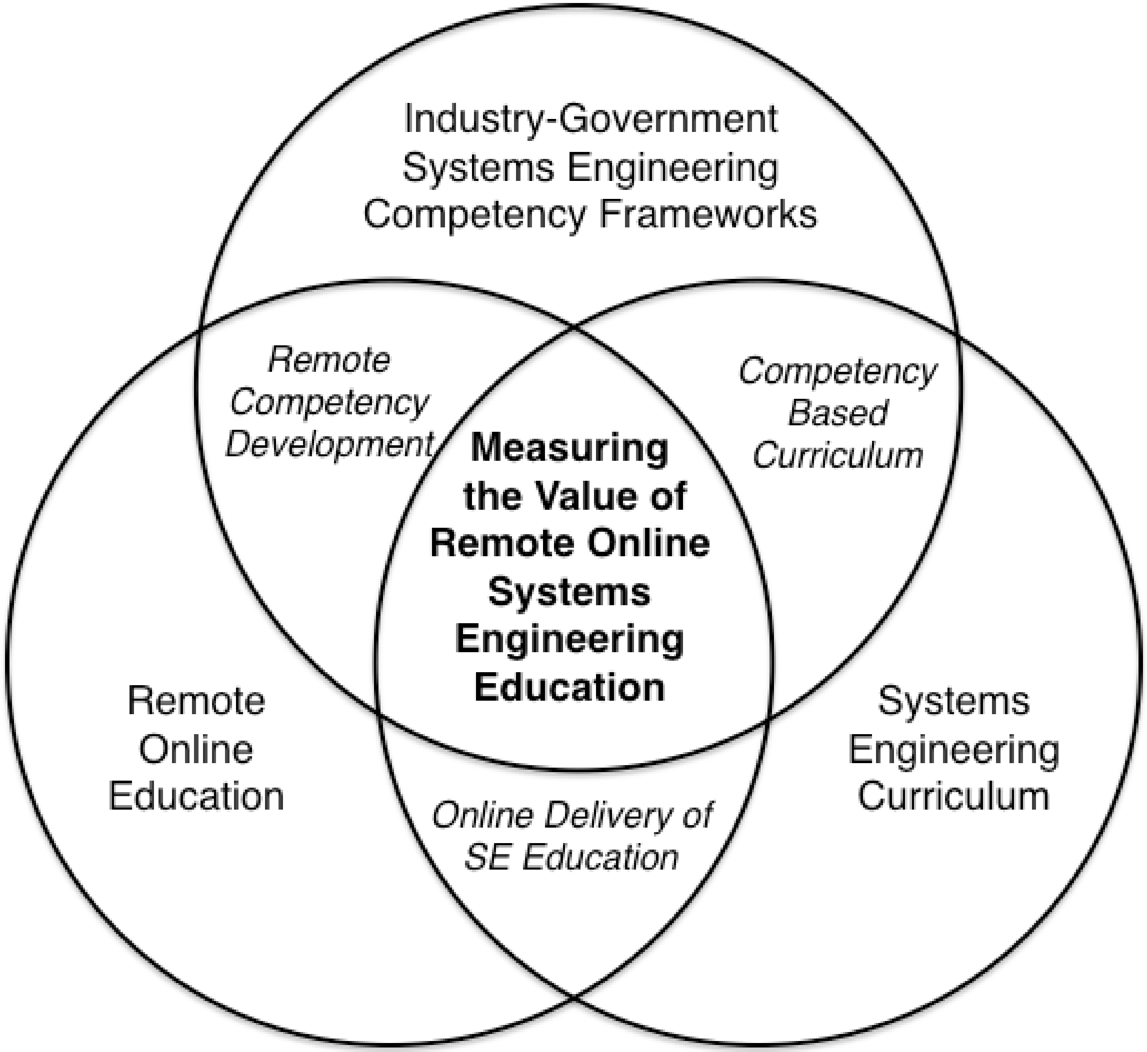
The Problem

According to the NDIA SE Division, one of the top five systems engineering issues for the Department of the Defense (DoD) is:

"The quantity and quality of systems engineering expertise is insufficient to meet the demands of the government and defense industry." (NDIA SE Division, 2010)

Problem Space

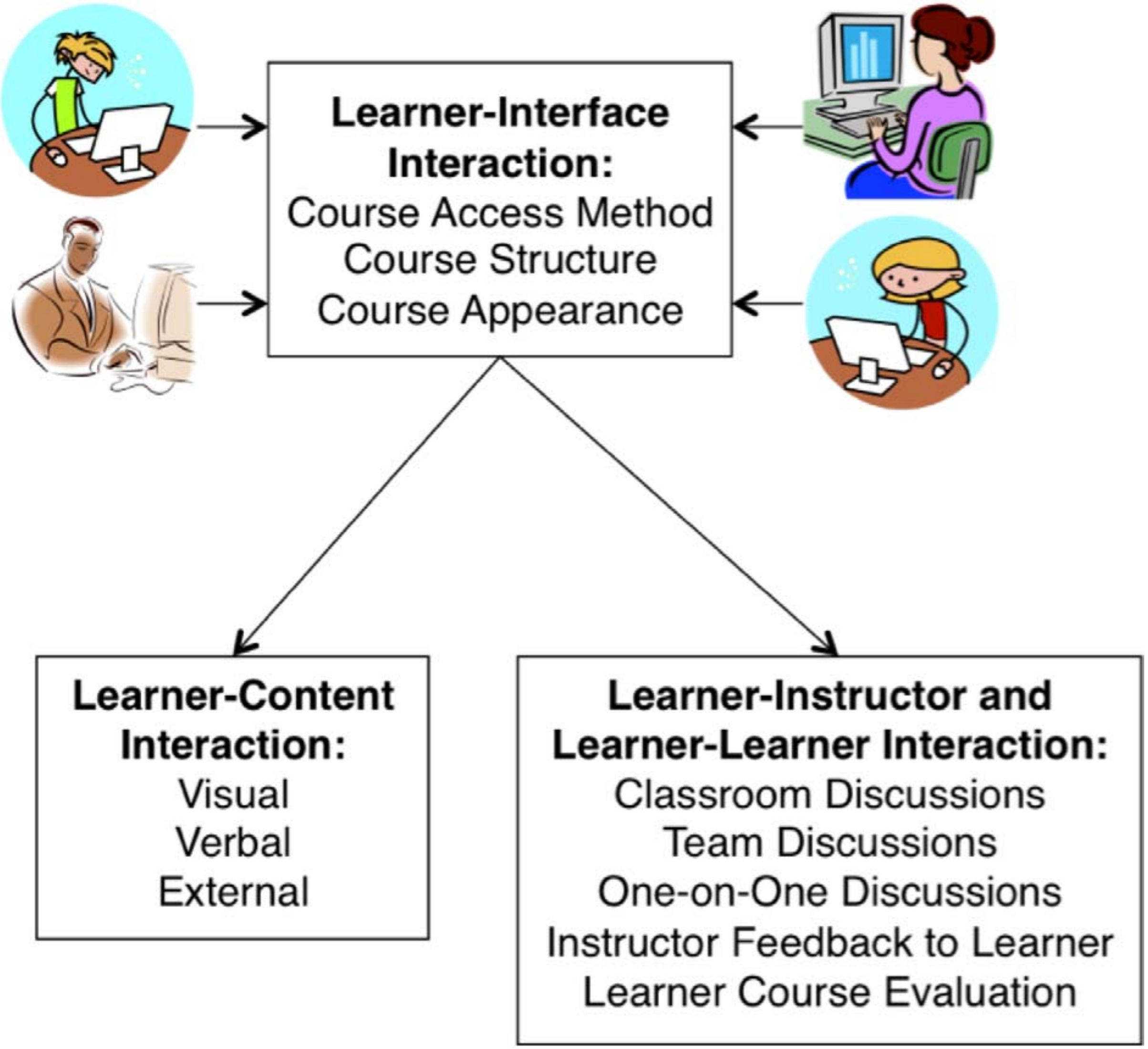


The Problem Continued...

BUT

The impact of remote online systems engineering education and training on student learning is not well known or understood.

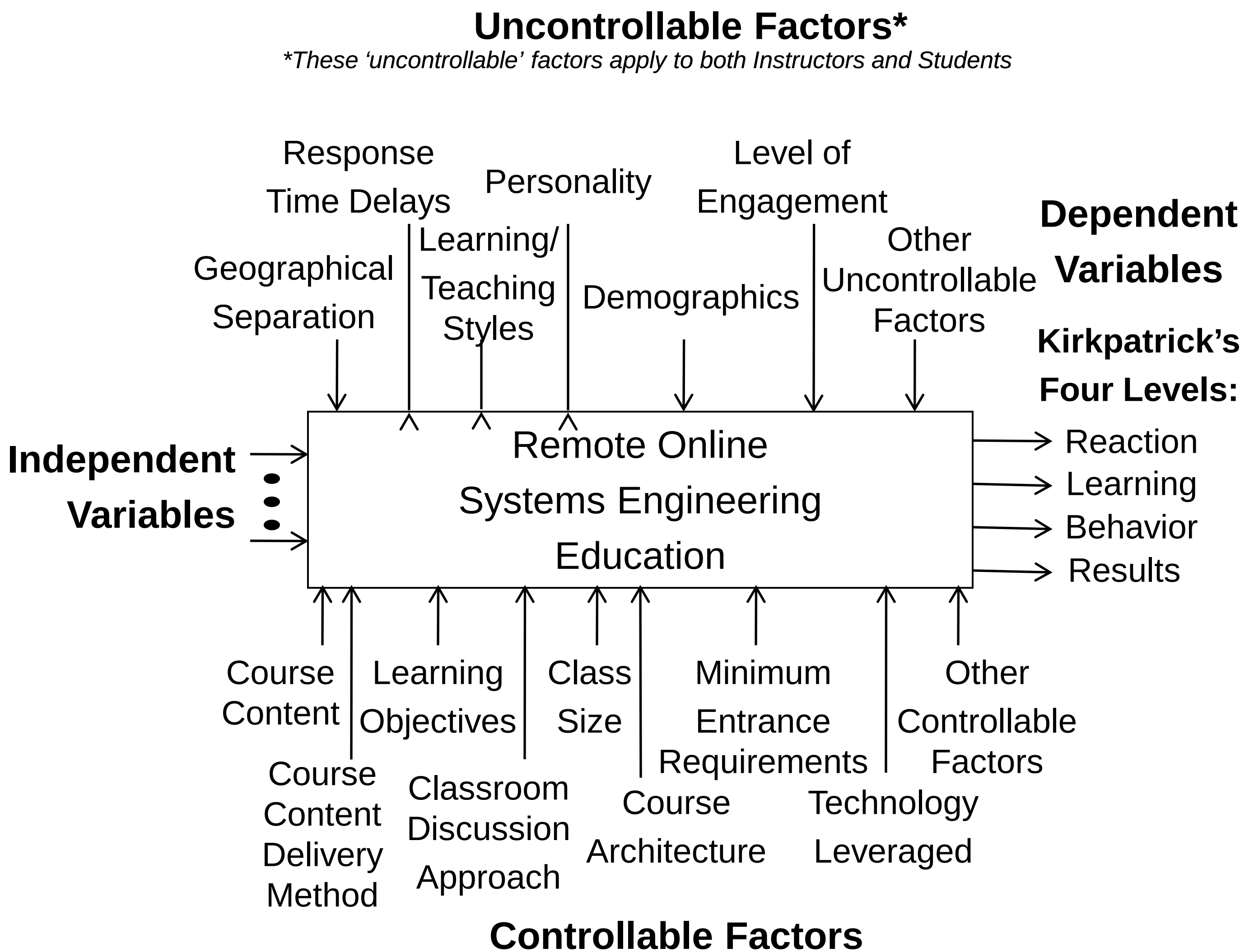
Remote Online Classroom Architecture



Early Systems Engineering Remote Online Education Research

- Squires, Pennotti & Verma (2006): case study - impact of audio lectures on student satisfaction and learning
  - 1 course, 7 instantiations, 131 students. Findings:
    - Audio lectures related to an increase in student satisfaction
    - No noticeable difference in student learning
- Squires & Pennotti (2007): which components of remote online learning impacted student satisfaction
  - 12 courses, 37 instantiations, 379 of 438 evals. Findings:
    - Top correlation: frequency and detail of faculty feedback
- Squires & Cloutier (2010): impact of classroom discussions on student satisfaction
  - 22 courses, 32 instantiations, 445 of 485 evals. Findings:
    - Classroom discussions related to student satisfaction, whether or not the faculty participated in those discussions

Current Version of Overall Framework



Research Hypotheses

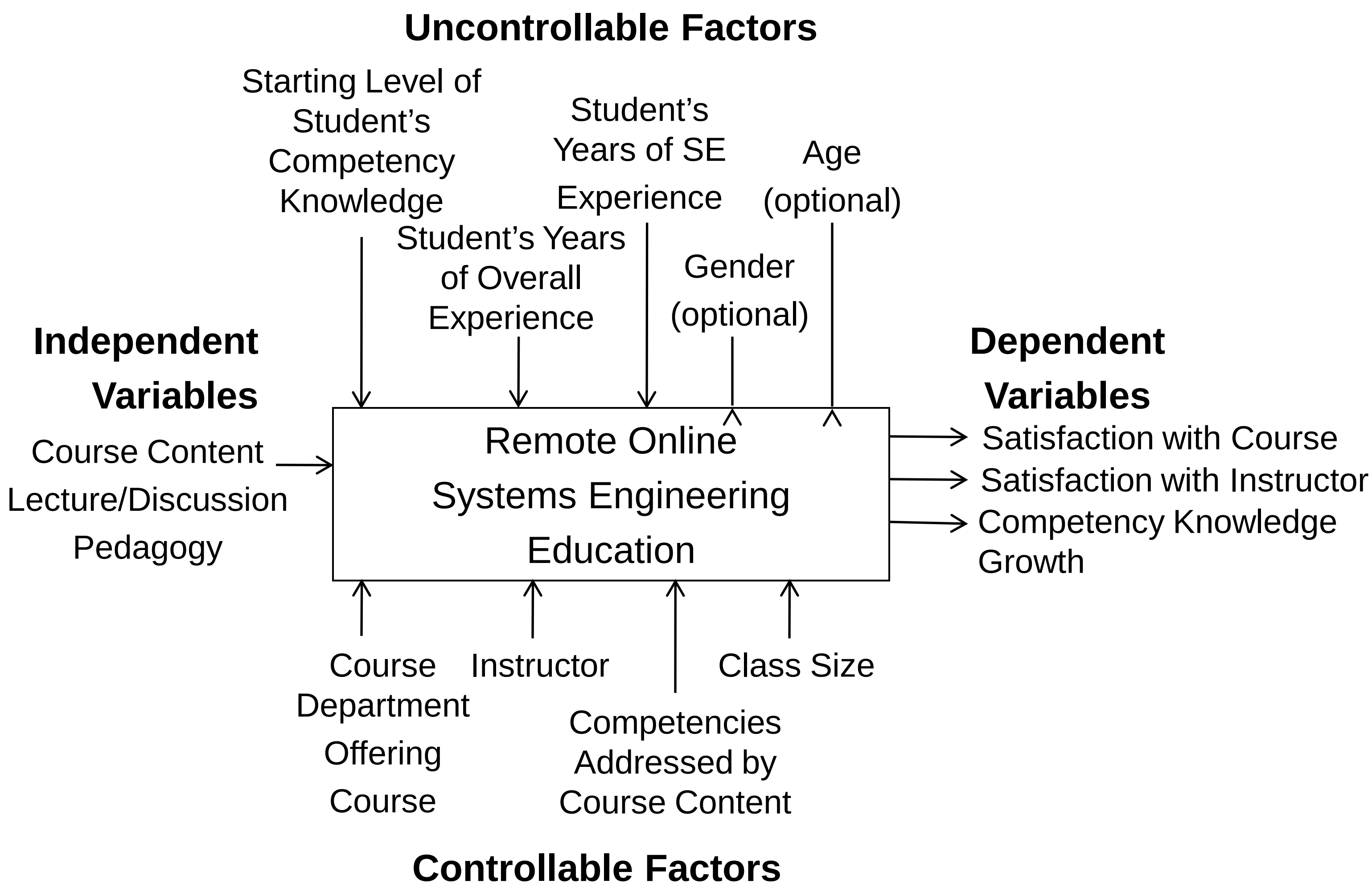
1. A student's level of satisfaction with a successfully completed remote online class…

2. A student's level of satisfaction with the instructor of a successfully completed remote online class…

3. The change in a student's perceived level of knowledge of systems engineering competencies, after successfully completing a remote online class,…

…is related to the pedagogical approach used by the instructor to deliver lectures and discuss course content during the delivery of the course.

Research Experiment and Additional Data



Operational Definitions: Student Satisfaction with Instructor and with Course

- Self reported by students through a survey.
- Degree to which they agree or disagree with the following two statements:
  - The instructor was an effective teacher.
  - This was an excellent course.
- Equally spaced values on a 0 to 100 scale:
  - Strongly Agree = 100
  - Agree = 75
  - Neither Agree or Disagree = 50
  - Disagree = 25
  - Strongly Disagree = 0

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NASA/Industry (APPEL, 2009) Model (1 of 3)

1.0 Concepts and Architecture	1.1 Form Mission Needs Statement
	1.2 Describe System Environments
	1.3 Perform Trade Studies
	1.4 Create System Architectures
2.0 System Design	2.1 Define/Manage Stakeholder Expectations
	2.2 Define Technical Requirements
	2.3 Logically Decompose System
	2.4 Define System Design Solution
3.0 Production, Product Transition and Operations	3.1 Implement the Product
	3.2 Integrate System
	3.3 Verify the System
	3.4 Validate the System
	3.5 Transition the System
	3.6 Conduct Operations

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NASA/Industry (APPEL, 2009) Model (2 of 3)

4.0 Technical Management	4.1 Plan Technical Effort
	4.2 Manage Requirements
	4.3 Manage Interfaces
	4.4 Manage Technical Risk
	4.5 Manage Configuration
	4.6 Manage Technical Data
	4.7 Assess Technical Product and Process
	4.8 Manage Technical Decision Analysis Process
5.0 Project Management and Control	5.1 Oversee Technical Acquisition
	5.2 Manage Resources
	5.3 Manage Contracts
	5.4 Manage/Implement Systems Engineering

NASA/Industry (APPEL, 2009) Model (3 of 3)

6.0 Organizational Environments	6.1 Understand Organizational Structure, Mission, Goals
	6.2 Apply PM/SE Procedures and Guidelines
	6.3 Manage External Relationships
7.0 Human Capital Management	7.1 Manage Technical Staff Organization and Performance
	7.2 Manage Team Dynamics
8.0 Security, Safety and Mission Assurance	8.1 Organize Security
	8.2 Organize Safety and Mission Assurance
9.0 Professional and Leadership Development	9.1 Coach and Mentor Protégés
	9.2 Communicate Highly Effectively
	9.3 Lead Teams and Organizations
10.0 Knowledge Management	10.1 Capture, Organize and Distribute Knowledge

Student Survey

1. Welcome! Provides general direction, expressed thanks
2. Experience: years of overall and systems engineering specific [required]; student and work status [optional]
3. Education: Background
4. Course Completed: used to confirm in population. Data for course, types of course content delivery and discussion used, student's overall satisfaction with course and instructor.
5. Competency Level: most intensive (and takes the longest time) page of the survey. Data for competency knowledge growth in 37 competencies.
6. Final Page: Optional data on age range and gender.

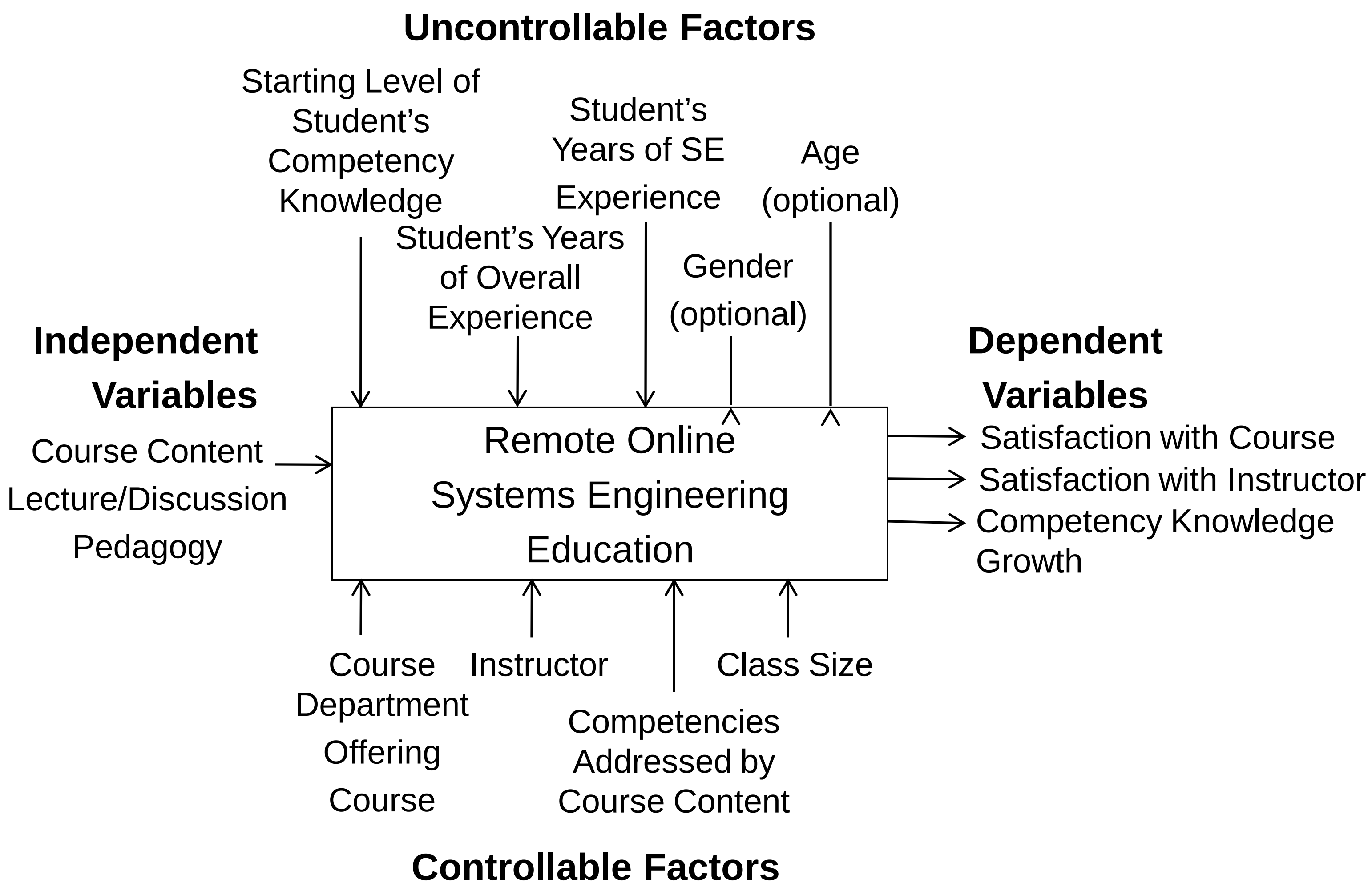
Instructor Survey

1. Welcome! General direction, expressed thanks
2. Course Taught: Information on course, types of course content delivery and discussion used.
3. Competency Level: Data for instructor's perception of which 37 competencies are covered in the course and at what level of knowledge.
4. Final Page: Thanks and final comments.

Population

- Students that completed one or more Stevens Webcampus courses in the Spring 2010 semester in:
  - Systems Engineering (includes space, security, enterprise)
  - Engineering Management
  - Software Engineering
- 422 student enrollments / 349 students:
  - 281 students (80.7%) in one Webcampus course
  - 62 students (17.8%) in two Webcampus courses
  - 3 students (0.9%) in three Webcampus courses
  - 2 students (0.6%) in four Webcampus courses
- 21 courses, 27 sections, 21 different instructors

Research Experiment and Additional Data



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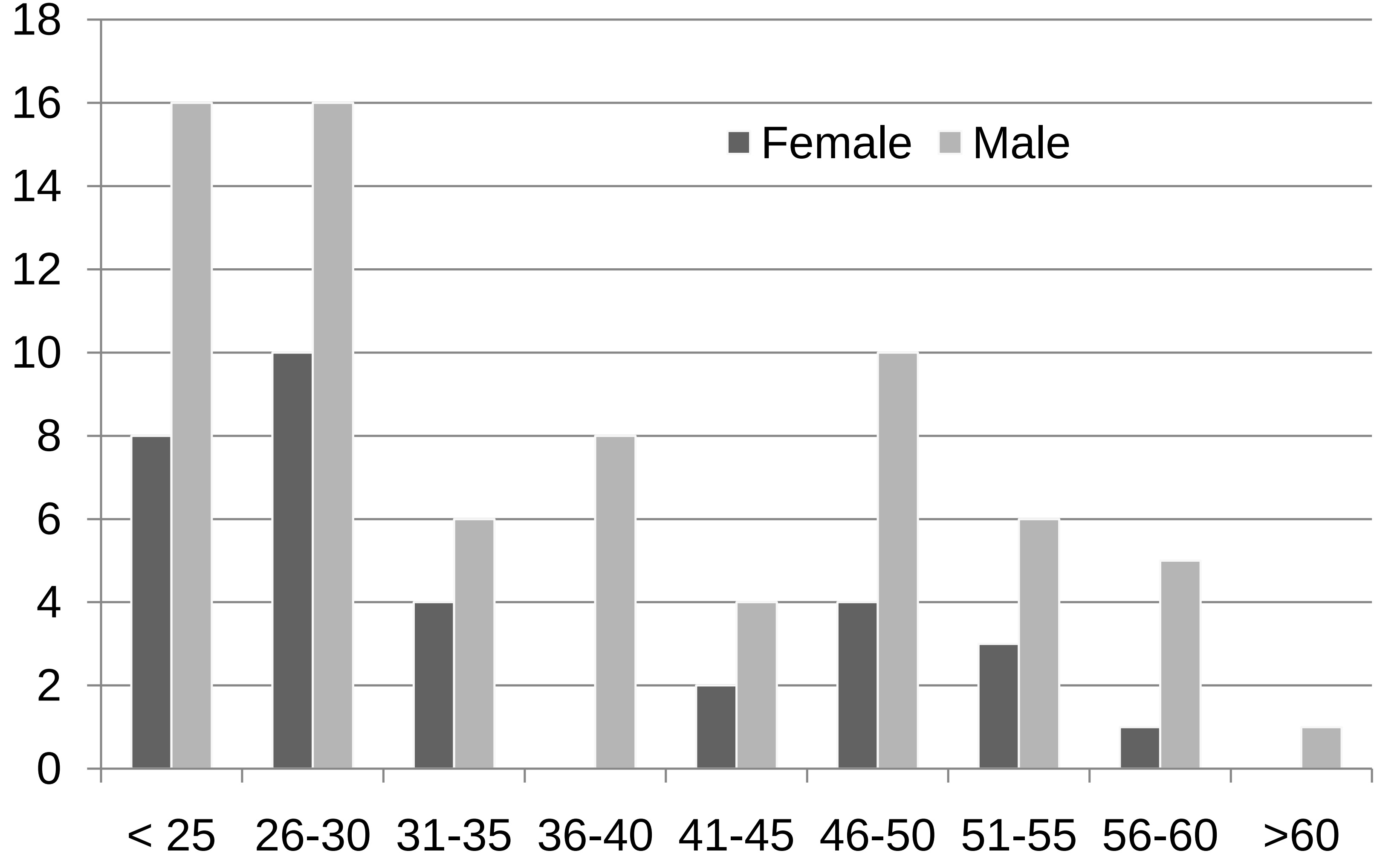
Analysis: Return Rates

Confidence Level:	**99%**	**95%**	**90%**
Constant z_N (two-sided):	**2.58**	**1.96**	**1.64**
Response Distribution (p):	**50%**	**50%**	**50%**
Finite Population (Pop):	**422**	**422**	**422**
Target Return Rate:	**20%**	**20%**	**20%**
Sample Size, SPLIT Sample:	42.2	42.2	42.2
Confidence Interval/Margin of Error (CI):	18.9%	14.3%	12.0%
Student Satisfaction Return Rate:	**37.7%**	**37.7%**	**37.7%**
Sample Size, SPLIT Sample:	79.5	79.5	79.5
Confidence Interval/Margin of Error (CI):	13.0%	9.9%	8.3%
Competency Knowledge Return Rate:	**25.35%**	**25.35%**	**25.35%**
Sample Size, SPLIT Sample:	53.5	53.5	53.5
Confidence Interval/Margin of Error (CI):	16.5%	12.5%	10.5%

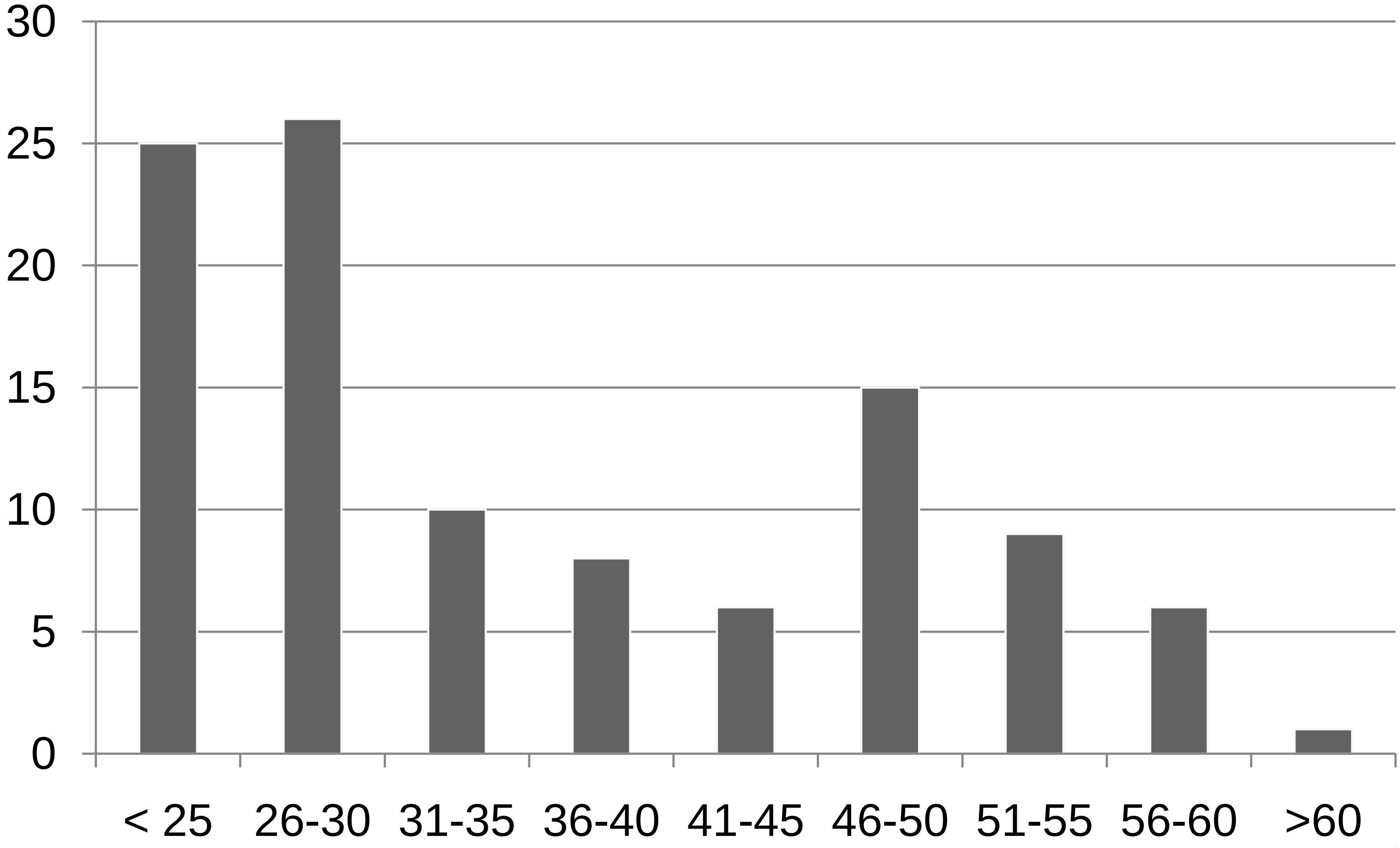
Return Rate 'Spread'

- Education and Experience: 159 student enrollments
  - Systems Engineering – 99 (62%)
  - Engineering Management – 40 (25%)
  - Software Engineering – 20 (13%)
- Plus Competency: 107 student enrollments
  - Systems Engineering – 70 (65%)
  - Engineering Management – 26 (24%)
  - Software Engineering – 11 (10%)
- Instructor Survey Return: 100%
  - Systems Engineering – 15 Courses, 12 instructors
  - Engineering Management – 7 Courses, 5 instructors
  - Software Engineering – 5 Courses, 4 instructors

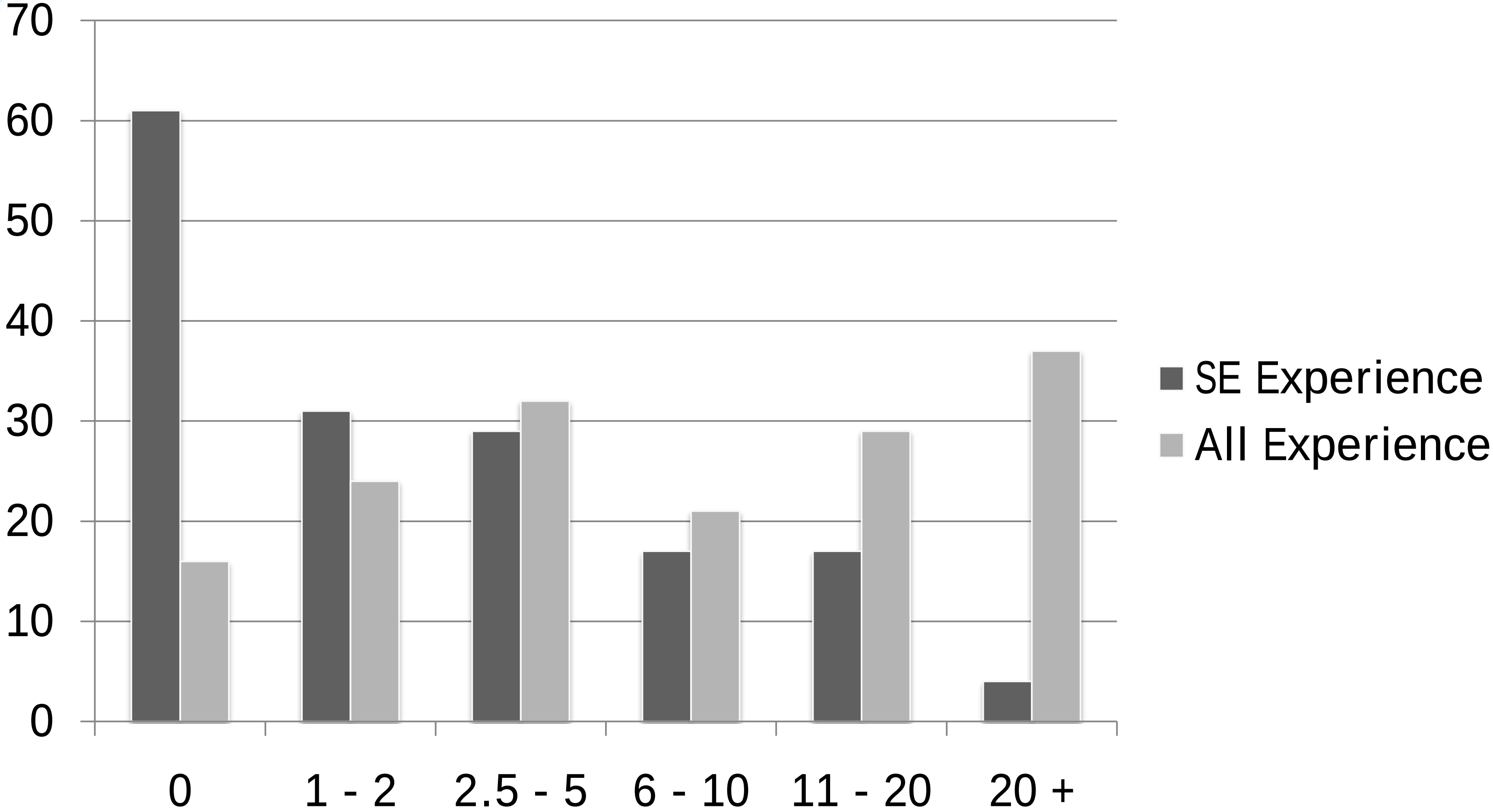
Sample: Age and Gender



Look Familiar?



Overall Experience/SE Experience



Preliminary Findings: Age/Gender/Experience

- Age:
  - About half are under 30 years.
  - About one-sixth are 30 – 40 years.
  - About one-third are over 40 years.
- About 70% Male, 30% Female
- Net Experience:
  - 10% have no professional experience
  - 38% have no SE Experience
  - 25% have 2 years or less of experience
  - 50% have 2 years or less of SE experience
  - Almost half have 5 years or less of experience in general
  - Over 75% have 5 yrs or less SE experience

Operational Definition: Competency Knowledge Growth

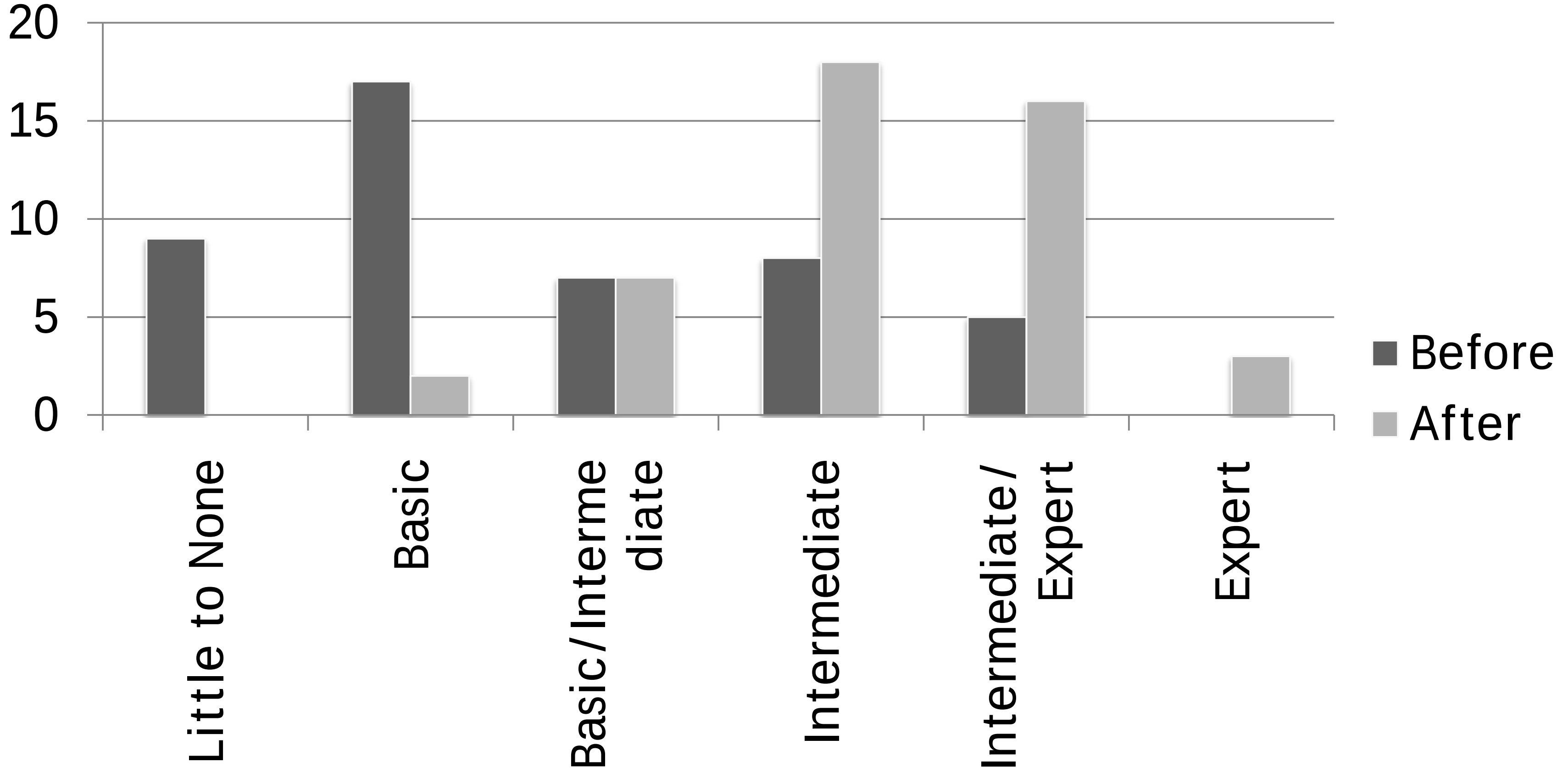
- Assumption: a change in the level of knowledge in a particular area of competency reflects learning.
- Self reported by students through a survey.
- Levels of knowledge are defined as:
  - Basic: You are able to understand a discussion about and follow directions related to the competency.
  - Intermediate: You are comfortable making decisions about and leading discussions related to the competency.
  - Expert: Many others look to you for knowledge about the competency.

Competency Knowledge Selections

- Students (and instructors) were asked to rate whether the competency was covered in the course (Yes or No).
- And what the level of competency was that the student had (or should have) coming into the course (before) and after successfully completing the course (after)
- The selections were:
  - Little to No knowledge
  - Basic level
  - Between Basic and Intermediate
  - Intermediate level
  - Between Intermediate and Expert
  - Expert knowledge

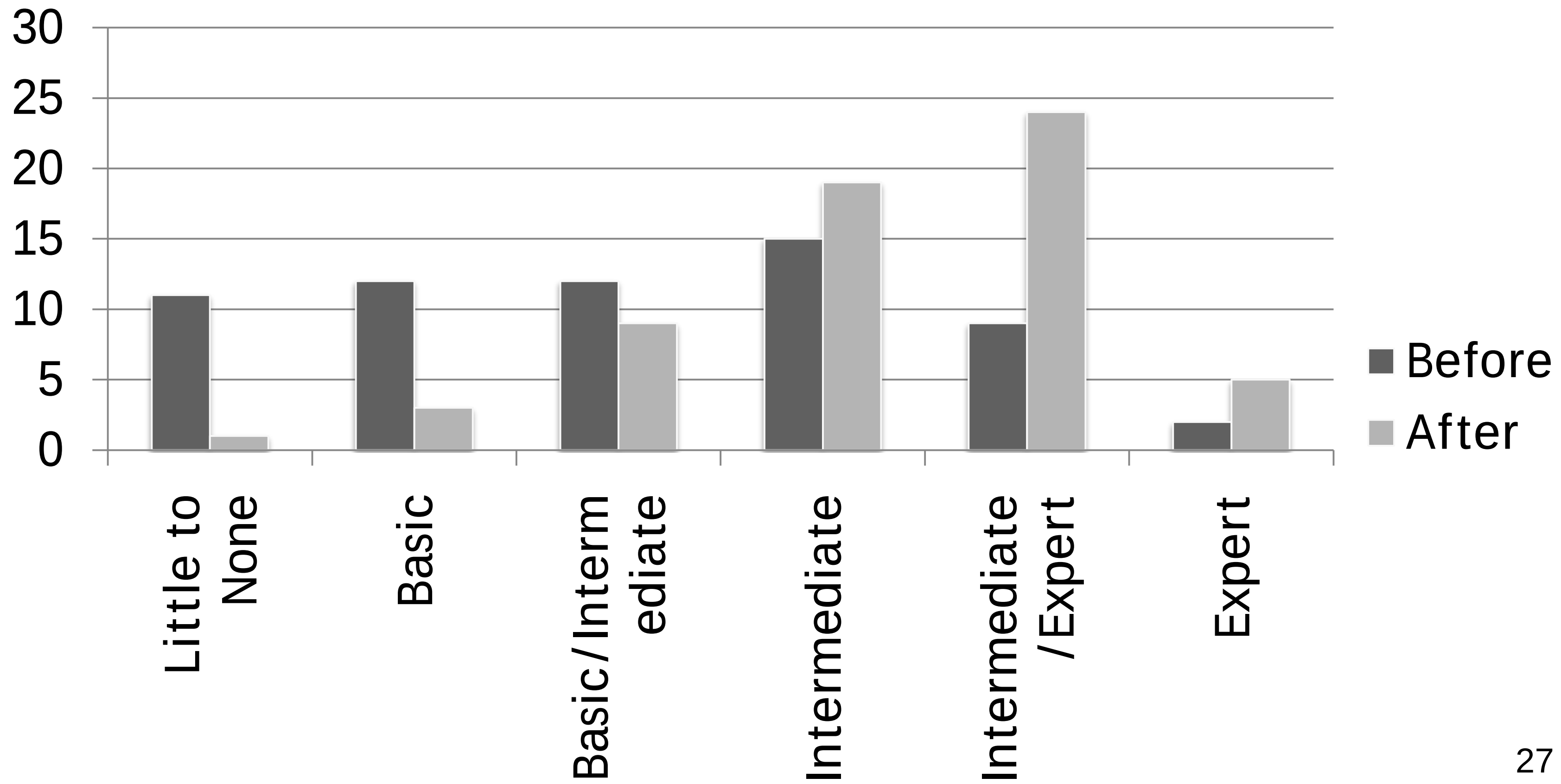
Concepts and Architecture: Form Mission Needs Statement

- Covered in Course? 43% said 'Yes'



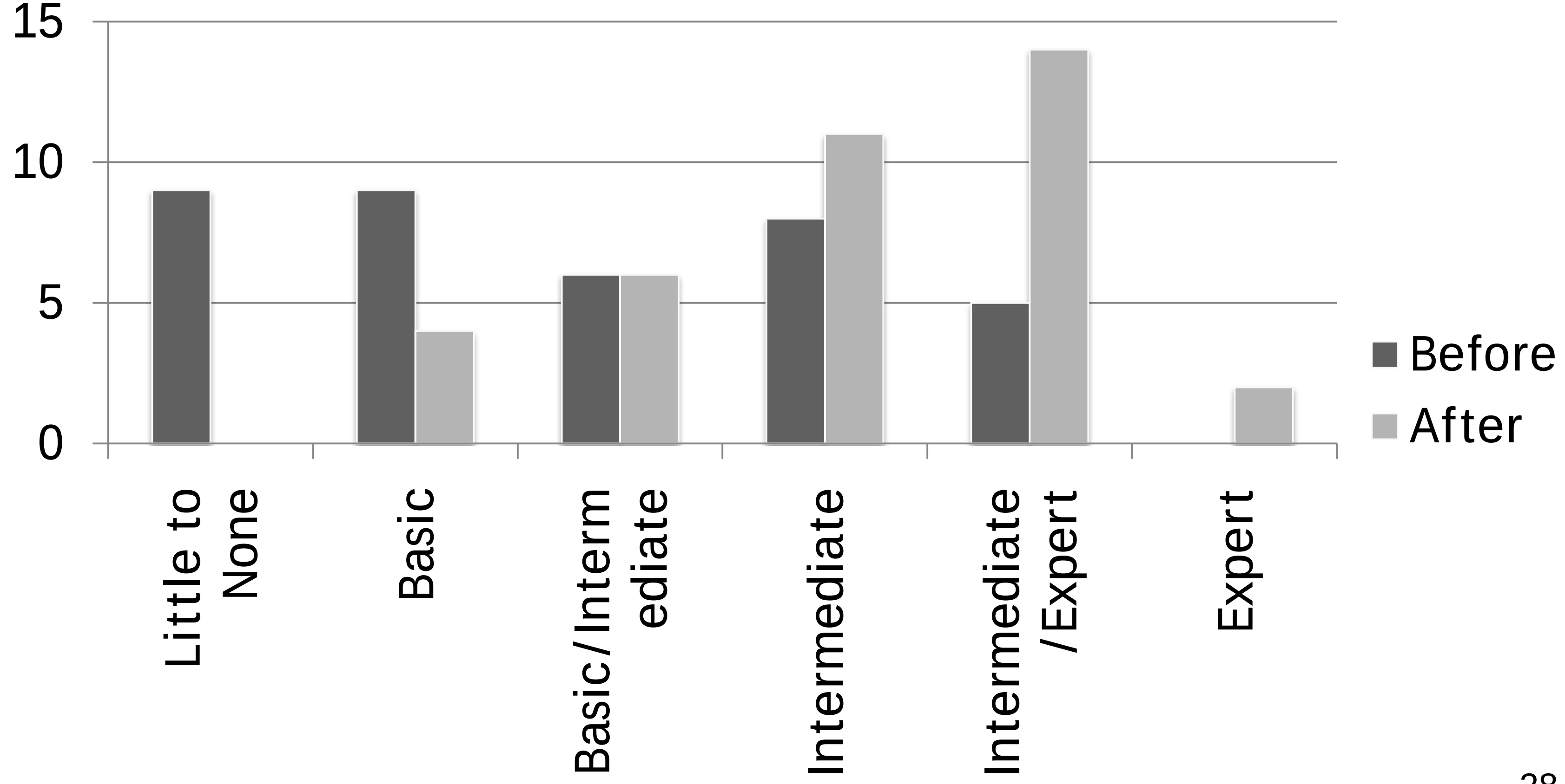
Concepts and Architecture: Describe System Environments

- Covered in Course? 57% said 'Yes'



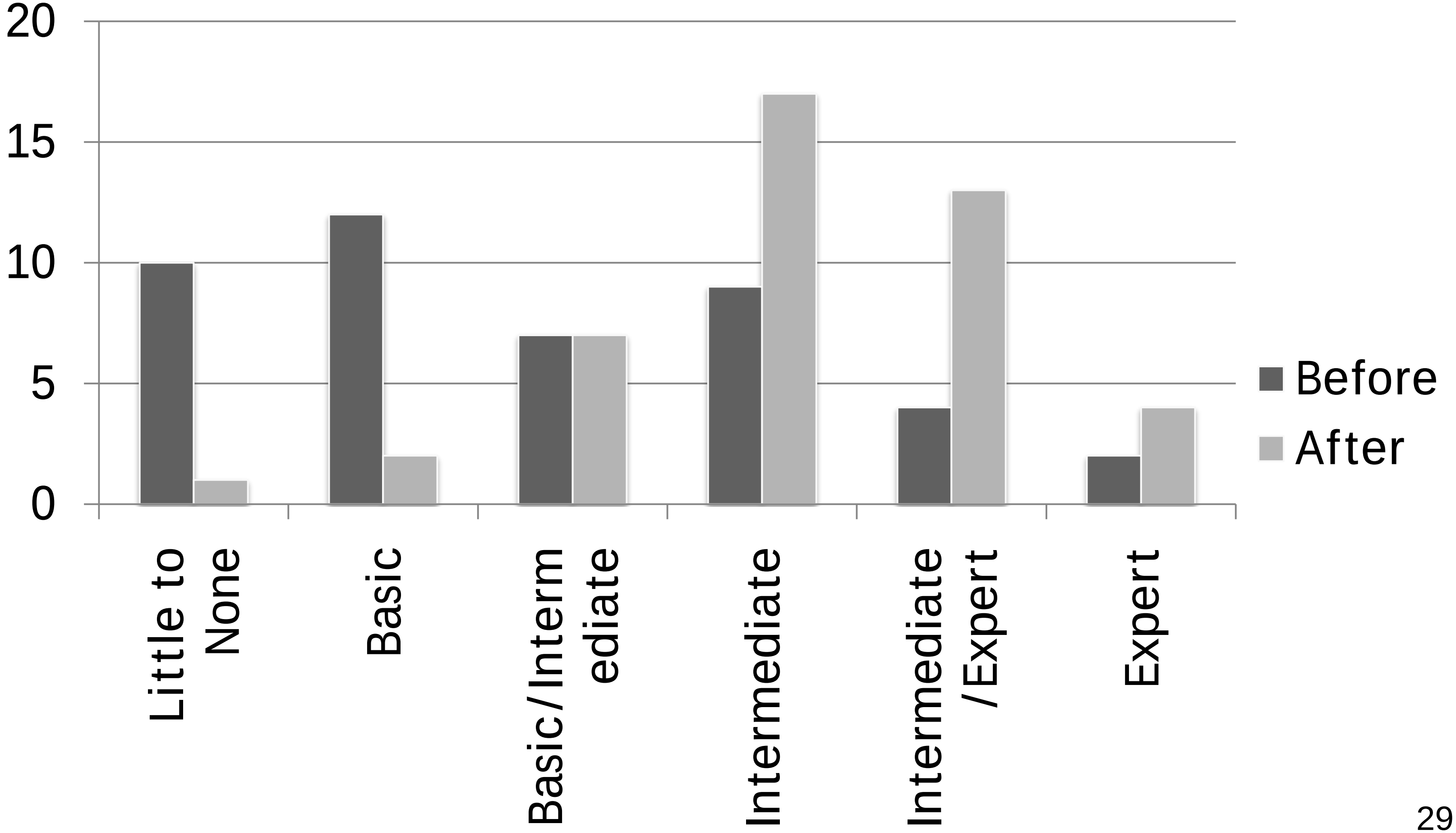
Concepts and Architecture: Perform Trade Studies

- Covered in Course? 35% said 'Yes'

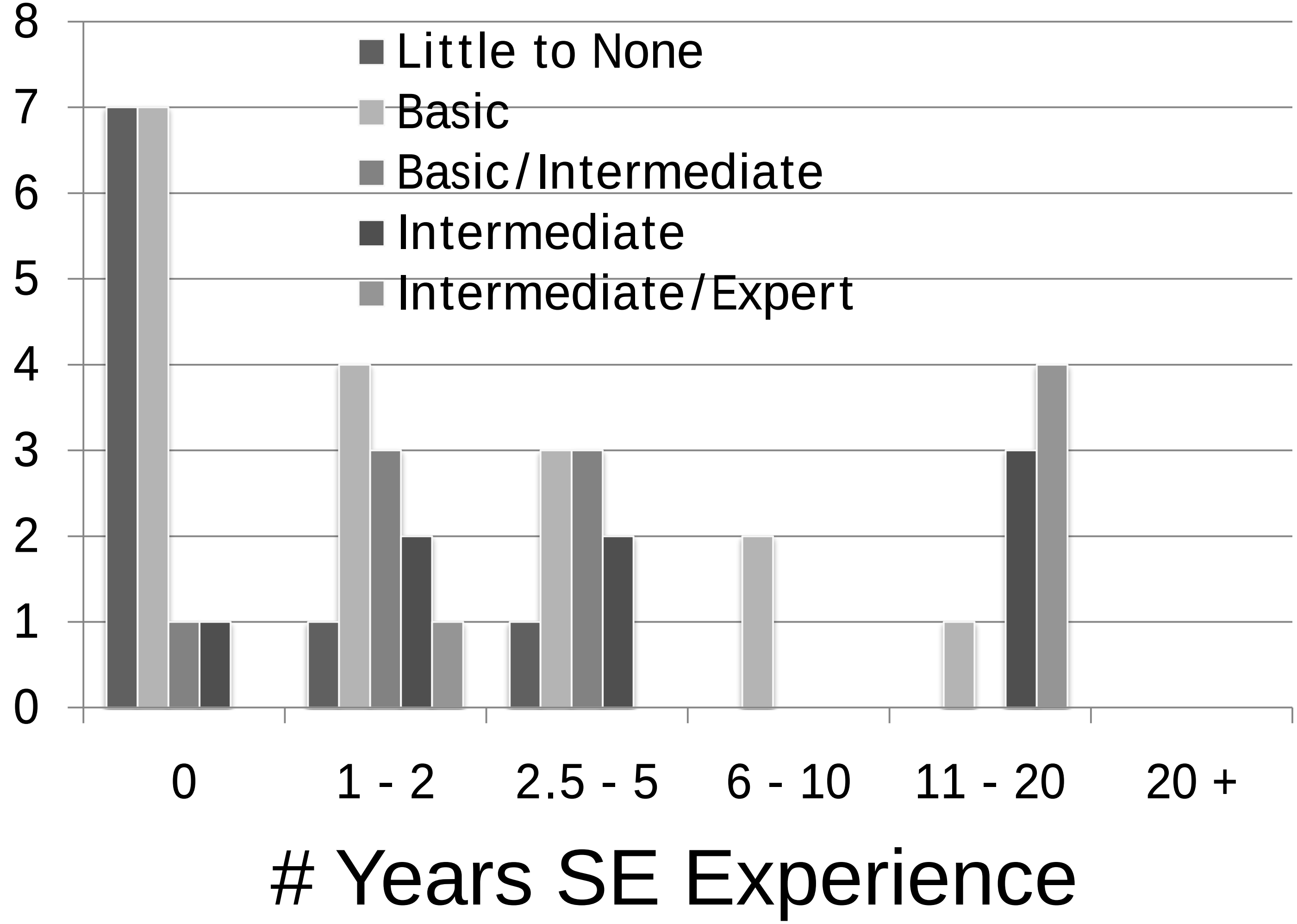


Concepts and Architecture: Create System Architectures

- Covered in Course? 41% said 'Yes'



Example Competency Roadmap: Form Mission Needs Statement



Preliminary Findings: Competency

- Students (and instructors) had different perceptions as to what competencies were covered in a particular course.
  - There was some general agreement in many cases.
- When a student felt that a particular competency was covered in the course content, they also felt that their level of knowledge in that competency tended to increase in general with the following noted:
  - The lower the level of perceived knowledge 'before' resulted in a larger increase from before to after, especially when the level started at 'little to no knowledge' or 'basic knowledge'.
  - In some cases the perceived level did not change, but primarily when the level was 'Intermediate' or above.

Research Objectives (1 of 2)

- To broaden awareness of both the need to assess remote online systems engineering education, and the challenges associated with this endeavor.
- To provide empirical evidence of the impact on student learning of systems engineering competencies when using specific pedagogical approaches to deliver course lectures and run classroom discussions in a remote online classroom.
- To provide empirical evidence of the impact on student satisfaction with the learning experience. Other observed impacts will be noted for possible future investigation.

Research Objectives (2 of 2)

- To further develop a robust design based framework that is intended to be extensible going forward to other modalities of systems engineering education as well as related educational domains.
- To continue the effort to identify the driving factors for measuring success in achieving an increase in student systems engineering competency development through remote online education.
- To test, validate, and assess the feasibility of a specific research approach for measuring student learning of systems engineering competency.

Backup Slides

Operational Definition: Course Content Lecture/Discussion Pedagogy

Score	Lectures	Discussions
10	Real-time Lectures + Slides	Text-based + Real-time Discussion
9		Text-based + Recorded Discussion
8	Real-time Lectures OR Audio Lectures + Slides	
7		
6	Audio Lectures	Real-time Discussions
5		Recorded Discussions
4		Text-Based Discussions
3		
2	Lecture Slides	
1		
0	No lectures	No course content discussion

Frequency Values Defined

- Frequency of lectures /discussions range from 0 to 10:
  - Never = 0
  - A Few Times During Course = 2
  - Every Other Week = 5
  - Almost Weekly = 8
  - Weekly = 10
- The possible range of values for the sum of all possible methods used to deliver lectures multiplied by the possible frequency that method was used, is 0 to 100.
- Similarly, the possible range of values for discussions is 0 to 100.

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Example: Lecture Values

Real-Time (Wt = 8)	Recorded (Wt = 6)	Slides (Wt = 2)	Value
Weekly	--	Weekly	100
Every Other Week	Every Other Week	Weekly	90
--	Weekly	Weekly	80
Every Other Week	Every Other Week	Never	70
Every Other Week	Never	Every Other Week	50
Few Times A Course	Every Other Week	Few Times A Course	50
Never	Every Other Week	Weekly	50
Never	Few Times A Course	Weekly	32
Few Times A Course	Never	Never	16
Never	Never	Few Times A Course	4
Never	Never	Never	0

Example: Discussion Values

Real-Time (Wt = 6)	Recorded (Wt = 5)	Text-Based (Wt = 4)	Value
Weekly	--	Weekly	100
Every Other Week	Every Other Week	Weekly	95
--	Weekly	Weekly	90
Every Other Week	Every Other Week	Never	55
Every Other Week	Never	Never	30
Few Times A Course	Few Times A Course	Few Times A Course	30
Never	Few Times A Course	Every Other Week	30
Never	Never	Never	0

Course Content Pedagogy (CCP) Value Defined

- Combines course content lectures and discussions
- Normalizes from 0 to 100
- Equally weighted (50% each)

$$CCP = 0.5 * \sum_{i = 1 \text{ to } 3} F_i * L_i + 0.5 * \sum_{j = 1 \text{ to } 3} F_j * D_j$$

- Where
  - F = Frequency
  - L = Lectures
  - D = Discussions

Example: Course Content Pedagogy

Course Content Pedagogy Used	CCP Value
Real-Time Weekly Lectures, Weekly Lecture Slides are Posted, Real-Time Weekly Discussions, Weekly Text-Based Discussions	100
Every Other Week: Real-time Lectures/Discussions, Lecture Slides are Posted, Text-Based Discussions	50
Recorded Weekly Lectures, Weekly Lecture Slides are Posted	40
Weekly Lecture Slides are Posted, Weekly Text-Based Discussions	30
Weekly Lecture Slides are Posted	10

Competency Knowledge Growth Value Defined (1 of 2)

- A transition at the higher levels (above intermediate) represents a greater step than a transition at the lower levels (below intermediate).
- Weighted values defined on a scale of 0 to 100 (LCK):
  - 0 - Little to No knowledge
  - 10 - Basic level
  - 30 - Between Basic and Intermediate
  - 50 - Intermediate level
  - 75 - Between Intermediate and Expert
  - 100 - Expert knowledge

Competency Knowledge Growth Value Defined (2 of 2)

- Competencies 'covered' in course (CIC):
  - Perspective of instructor through instructor survey
  - Perspective of students through student survey
- For those competencies 'covered', before and after levels of competency attainment collected from students (self perception) for all 37 competencies.
- Final competency knowledge growth value: difference between value 'after' course completed (CKA) less value 'before' course started (CKB):

$$CKG = CKA - CKB, \text{ where}$$

$$CKA = \sum_{i = 1 \text{ to } 37} CIC_i * LCKA_i \quad \text{and} \quad CKB = \sum_{i = 1 \text{ to } 37} CIC_i * LCKB_i$$

Example: Course 'Covers' Ten Competencies

	Before	After
Competency 1	Basic	Basic
Competency 2	Basic/Intermediate	Intermediate
Competency 3	Basic	Basic/Intermediate
Competency 4	Intermediate	Intermediate
Competency 5	Intermediate	Intermediate/Expert
Competency 6	None	Basic
Competency 7	Expert	Expert
Competency 8	Basic/Intermediate	Basic/Intermediate
Competency 9	Basic	Basic/Intermediate
Competency 10	None	Basic

CKB Value: 290

CKA Value: 395

CKG Value: 105

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Systems Engineering Education

Type of SE Program	Degree Level	Brown & Scherer (2000)	Fabrycky (2010)	Squires (2010a)* Remote Online	2000 to 2010 Increase Factor
Systems Centric	Bachelors	10	11	*	1.1
	Masters	10	31	14	3.1
	Doctorate	3	14	*	4.7
	Systems Centric	23	56	14	2.4
Domain Centric	Bachelors	9	44	*	4.9
	Masters	17	42	4	2.5
	Doctorate	9	23	*	2.6
	Domain Centric	35	109	4	3.1
All	Bachelors	19	55	-	2.9
	Masters	27	73	18	2.7
	Doctorate	12	37	-	3.1
All	All Degrees	58	165	18	2.8

*Only Remote Online Masters Degrees investigated; however, no evidence of completely remote online SE undergraduate or PhD degrees found during investigation.

Remote Online: Subset of Distance Education

Traditional Classroom | Radio | Interactive Television | Video Conferencing | Web conferencing over the Internet

Face-to-Face → **Regionally** → **Domestically / Global**

Real-time 'Space' Continuum

See Real-Time 'Space' Continuum | '**Remote Online**' Semester Based Course | Correspondence Course Through Postal Service | Self-Paced Online Learning

Real-Time → **Days** → **Weeks** → **Months** → **Years**

'Time' Continuum

[Distance Education] Evaluation Frameworks

Community of Inquiry (COI) Framework	An instrument for measuring social presence, teaching presence and cognitive presence in computer mediated conferences (online discussions)
Learner Interactions Model	Focused on interactions between learner-content, learner-instructor, learner-learner and learner-interface
Interaction Analysis Model	Groups analysis of computer mediated conferencing interaction into sequential knowledge development phases leading to newly constructed meaning
The Unfolding Model	Combines scientific quantitative approaches and qualitative research methods resulting in multiple perspectives for evaluating processes and outcomes in distance education.
Kirkpatrick's Four Levels	An approach for evaluating training programs that assesses the training through four levels: 1) student reaction to the training, 2) student learning, 3) change in student behavior on-the-job, and 4) the results or bottom line impact to the organization.
Bloom's Taxonomy for the Cognitive Domain	Used to categorize the level of cognition from amongst six levels, each of which builds on obtainment of the previous level, as follows: 1) Knowledge, 2) Comprehension, 3) Application, 4) Analysis, 5) Synthesis, and 6) Evaluation.

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Publication Strategy (1 of 2)

Authored Titles	Authors	Venue	Status
The Effect of Incorporating Verbal Stimuli in the Online Education Environment: An Online Case Study	Alice Squires Mike Pennotti Dinesh Verma	Proceedings from ASEE 2006 Annual Conference, Chicago, Illinois, June 18-21, 2006.	Peer-reviewed, Presented, Paper Published 2006
Measuring the Value of Course Components in the Online Classroom	Alice Squires Mike Pennotti	Proceedings from ASEE 2007 Annual Conference, Honolulu, Hawaii, June 24-26, 2007	Peer-reviewed, Presented, Paper Published 2007
Mapping Space-Based Systems Engineering Curriculum to Government-Industry Vetted Competencies for Improved Organizational Performance	Alice Squires Wiley Larson Brian Sauser	Systems Engineering Journal	Accepted; Paper published, 2010, 13(3)
Improving Systems Engineering Curriculum Using a Competency-Based Assessment Approach	Alice Squires Wiley Larson	International Journal of Intelligent Defence Support Systems: Special Issue on Systems Engineering Education	Accepted; published in 4th issue, 2009.
Evolving the INCOSE Reference Curriculum for a Graduate Program in Systems Engineering	Alice Squires Rob Cloutier	Systems Engineering Journal	Accepted; Paper published, 2010, 13(4)

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Publication Strategy (2 of 2)

Authored Titles	Authors	Venue	Status
Developing a Strategy to Measure Systems Engineering Competency Knowledge Development in the Remote Asynchronous Online Classroom	Alice Squires Rob Cloutier	Proceedings of the 8th Annual CSER 2010, Stevens Institute of Technology, Hoboken, New Jersey, USA, March 17-19, 2010	Peer-reviewed, Presented, Paper Published 2010
Evaluating the Effectiveness of Classroom Discussion Approaches Used in the Remote Delivery of Systems Engineering Education	Alice Squires Rob Cloutier	Proceedings of the ASEE 2010 Annual Conference, Lexington, KY, June 20-23, 2010.	Peer-reviewed, Presented, Paper Published 2010
Comparing Perceptions of Competency Knowledge Development in Systems Engineering Curriculum: A Case Study	Alice Squires Rob Cloutier	Proceedings of the ASEE 2011 Annual Conference, Vancouver, CA, BC, June 26-29, 2011.	Submitted abstract
Leveraging the Remote Online Classroom for Building Systems Engineering Competency Knowledge: A Detailed Case Study	Alice Squires Rob Cloutier	Systems Engineering	TBD
Measuring the Value of Systems Engineering Education in the Remote Online Environment	Alice Squires Rob Cloutier	Journal of Engineering Education	TBD