26th annual INCOSE international symposium
Edinburgh, UK
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Systems Thinking in Systems Engineering

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Background

- Systems Thinking related literature is found in various disciplines.
- The broad range of the Systems Thinking related literature generates disagreement about definition and understanding of systems thinking.
- Researchers disagree about what Systems Thinking is depending on their background discipline.

Background 2

- Some scholars view systems thinking as
  - A science
  - A method
  - An approach
- OR
  - A skill
  - A discipline
  - A conceptual framework
  - Recent sources discuss the ambiguities of systems thinking definitions.
- The conceptualisations of systems thinking have limited applicability in systems engineering.

Objectives

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- Clarify what systems thinking is.
- Discuss the categories found in the systems thinking literature from the early twentieth century.
- Propose a new systems thinking construct, and define its role in Systems Engineering.
- Draws the implications of the new systems thinking construct for systems engineering education.

Systems Thinking Classification

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- There are several classifications in the systems thinking literature

- Lane and Jackson (1995)
- Cabrera (2006)
- Ramage and Shipp (2009)

differentiate Systems Thinking literature according to the particular theoretical foundation of the work

and

- Luoma (2009)
- Mingers and White (2010)

divide the literature according to the purpose of the work

Systems Thinking literature can be divided into three branches:

- theoretical aspects of Systems Thinking
- methodological aspects of Systems Thinking
- practical aspects of Systems Thinking

Ancient Philosophy Underlying Systems Thinking

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- The ancient ideas of systems thinking emerged at the beginning of the various philosophical traditions. (Middle East, Greece, China, India etc)
- Systemic thought was embedded in the early cultural traditions.
- Systemic thought has remained a major intellectual form in the East.
- Eastern thinking pays more attention to the relations of parts.
  - The wholeness and interconnections that exist in nature.
  - Contrasts with the western emphasis on the essence of each part.
- The Eastern worldview regards all perceived things and events as interrelated, connected and manifestations of the ultimate reality.
  - This is a significant distinction with the western and Middle Eastern traditions.

Systems Thinking Classification

- Camelia and Ferris (2015) identified three factors in the analysis of a questionnaire investigating students' learning and appreciation of sytems thinking.

Perspective on the Nature of Systems Thinking	Related factors in the Learning of Systems Thinking by Camelia and Ferris (2015)
Systems thinking related theories and frameworks (tektology, general systems theory, cybernetics, systems complexity hierarchy, hard and soft systems and critical systems thinking)	Preference or inclination towards whole of systems perspectives
Systems thinking related methodologies (functionalist, interpretive and emancipatory)	Interest in the intended purpose or application of the whole system under consideration or development
Practical perspectives of systems thinking (methodologies and conceptual application).	Inclination towards participation in seeking a coherent, whole, system solution

- The two sets of classes, whilst different, are quite similar, indicating a natural structure to this trichotomy.

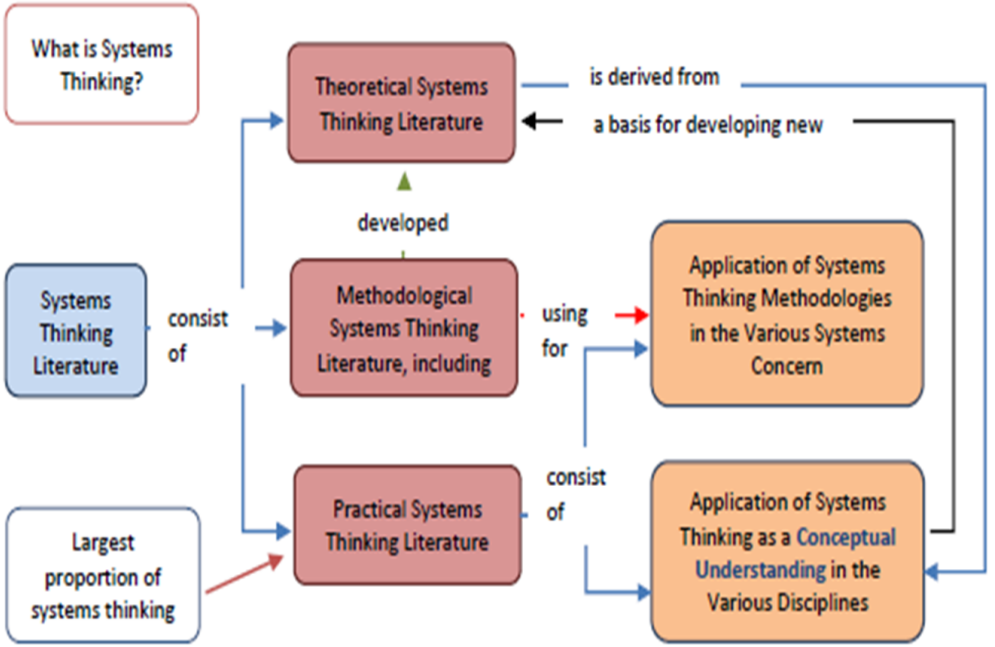
A Proposed Framework

Systems Thinking Definition:

The *conceptual understanding* or *mental constructs* about the *systems of interest* which involve *perception* and *conceptualization* processes performed by applying *systems thinking rules*:

- questioning systems boundary
- systems structure and interrelationship
- adopting multiple perspectives
- considering dynamic characteristics
- applying a holistic and big picture view

which can be improved by the use of *the most suitable systems thinking tools, methods or approaches.*



Second Questionnaire

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- The original questions were all constructed in positive grammar.
- A suggestion was made to have some questions with inverted grammar to avoid answer bias.
- The new question set was used with an independent set of subjects.
- Again results were analysed using Exploratory Factor Analysis and Confirmatory Factor Analysis methods.
- The result was identifying five categories.

The Two Structures of Systems Thinking

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Model 1 (M1)		Model 2 (M2)	
Factors in the learning of systems thinking	Perspective on systems thinking	Factors in the learning of systems thinking	Perspective on systems thinking
Inclination towards taking holistic view and interest in the activities of specialists in other areas	Cross-disciplinarity	Preference or inclination towards whole of systems perspectives	Theoretical
Interest in ensuring system coherence	Holism	Interest in the intended purpose or application of the whole system under consideration or development	Methodological
Interest in and enjoyment of using system modeling methods	Methods to do work	Inclination towards participation in seeking a coherent, whole, system solutions	Practical
Perception of interconnectedness of work tasks done in a team	Complexity and holism		
Inclination to teamwork and organization	Bureaucracy		

Observations

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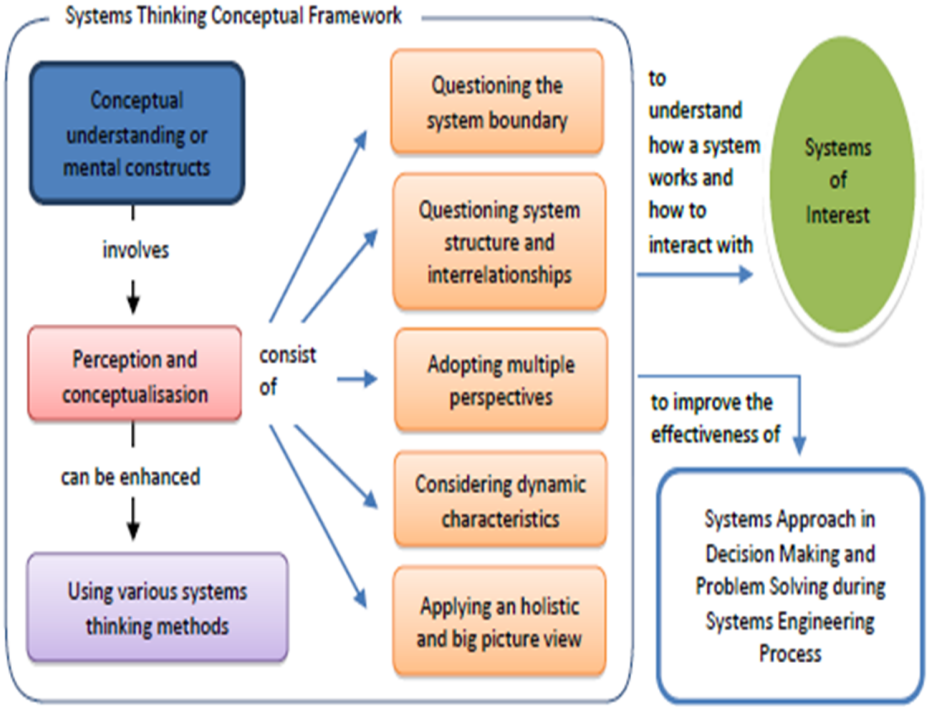
- M1 organises the systems thinking learning space around the affective characteristics of interest/engagement with systems thinking
  - Cross-disciplinarity
  - Holism
  - Methods to do work
  - Complexity and holism
  - Bureaucracy
- M2 organises the systems thinking learning space around the characteristics of a discipline:
  - Framework of idea
  - Methods
  - Practice – doing things

Interesting Outcome

- The 3 and 5 category models were both supported by the mixed questions survey (5 category slightly more strongly)
- The 3 category model organised the space according to cognitive domain categories
  - 3 category model was consistent with literature review construction of the systems thinking space
- The 5 category model organised the space according to affective domain categories
  - 5 category model was concerned with the way the student engaged with the subject matter – **interest in** and **belief in** the suitability and apppositeness of the systems thinking approach

Implications for SE

- Systems engineers do the work of perceiving and conceptualizing their systems of interest → make decisions and solve emergent problems during systems development.
- Systems engineers apply systems thinking methods and rules recursively until they obtain an internally consistent construct → the conclusion of their investigation.
- The rules are grounded in everyday thinking.
- The use of the rules can be enhanced through the more regular and conscious use.



Implications for SE

- The use of the rules can be further enhanced by the use of a variety of systems thinking related *methods or approaches*, including methods or approaches which are based on:
  - functionalist methodologies (e.g.: systems dynamics (Forrester 1971))
  - interpretative methodologies (e.g.: soft systems methodology (Checkland 1993))
  - emancipatory methodologies (e.g.: critical system heuristics (Ulrich 1983))
- Systems engineers will also use *visualizations tools* such as concept maps, mind maps and systemigrams to model the system (Boardman 2008).
- Systems engineers can also *design a new method or approach* which is the *most suitable* for a particular system using *combinations* of existing methods and tools.

Implications for SE Education

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- Since systems thinking involves *conceptualization* of the world

  → SE educators must establish both the theoretical and methodological aspects of systems thinking in systems engineering students.

  The theory and methods of systems thinking can be taught with methods focused on the ***cognitive domain*** of learning.

- However, since systems thinking also involves *perception* and *engagement* with the world, it is affected by the beliefs, values and assumptions that people hold.

  → SE educators must establish the ***affective domain*** of learning.

  Thus, systems engineer must be characterized by engagement with the cognitive content in a manner demonstrating **belief in** the value of the methods

Conclusion

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- The most important role of the systems thinking literature is as a conceptual framework.
- Systems engineers apply systems thinking to address matters of need and concern, especially during scope and objective formulation, decision making and problem solving.
- A systems thinking conceptual framework is the fundamental perspective of the systems engineer, who then uses the methods and techniques described by systems thinking scholars to strengthen their belief in the holistic approach.
- Systems engineering education must address both cognitive and affective domains in systems thinking and be equipped with suitable tools to measure the development of these capabilities.