Systems Thinking Scale

STS User Manual

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I. Introduction

Knowledge in an emerging field is advanced more rapidly when valid and reliable measures of the concepts central to that field are available. Systems Thinking is viewed as a key concept in the success of continuous quality improvement (CQI) initiatives, yet no valid and reliable instrument exists to measure Systems Thinking. This project was funded by the Robert Wood Johnson Foundation from 2008 – 2010 as part of their initiative to Advance the Science of Quality Improvement Research and Evaluation (ASQUIRE).

The goal of this project was to develop and conduct psychometric testing of the Systems Thinking Scale (STS), a measure of systems thinking in quality improvement work.++++++++++++++++++++++++++++

The development of a valid and reliable measure of Systems Thinking has the potential to contribute to the science of CQI in several ways:

1) Increase our understanding of one of the mechanisms by which CQI processes achieve their results;

2) Assist CQI scientists and practitioners to build models of predictors of successful CQI projects;

3) Increase our understanding of the human social capital available on CQI teams; and

4) Improve our education efforts of future CQI team members.

SYSTEMS THINKING SCALE (See Appendix A)

The Systems Thinking Scale is a 20-item instrument that uses a 5 point likert-type scale:

0= Never
1= Seldom
2= Some of the time
3= Often
4= Most of the Time

A total score is computed by summing up the responses for each item. Scores can range from 0 to 80.

Project Summary

Purpose of the Study: The goal of this Robert Wood Johnson Foundation-funded project was to develop and conduct psychometric testing of a measure of systems thinking - the Systems Thinking Scale (STS).

Methods:

First, using a series of electronic interactions, 10 international experts in systems thinking and process improvement identified the conceptual domains of systems thinking and generated a provisional set of 30 instrument items. These items were then assessed for content validity by academic and practicing healthcare professionals (n=18) and revisions to wording and response categories were made. Principal axis factor analysis with oblique rotation was used to assess construct validity; this resulted in dropping 4 items, thus providing a final measure of 26 items for psychometric analyses. Next, a series of psychometric analyses was conducted with healthcare professionals (N=342) and health professions students engaged in quality improvement initiatives and education (N=224). Reliability and concurrent, discriminate, and predictive validity of the STS were evaluated.

Results:

Factor analyses indicated three factors of the STS: 20 items loaded high on Factor 1 (System Interdependencies); 2 items loaded on Factor 2 (Personal Effort), and 4 items loaded on Factor 3 (Reliance on Authority). Because of the low number of items on Factors 2 and 3 and negative correlations among them, these items were omitted from further psychometric testing. Thus, reliability and validity were assessed using only the 20-item one-factor instrument. Test-retest reliability assessment (n=36) showed a correlation of .74; internal consistency testing (n=342) using Cronbach's Alpha had a coefficient of.89. Discriminate validity was tested with 3 groups of healthcare professions students (n= 102) who received high, low or no dose levels of systems thinking education related to process improvement. There were no differences in STS mean scores at pretest. At post test, the high dose systems thinking education group scored significantly higher on the STS than both the low and no dose groups (p=.05 and .01, respectively). Concurrent and predictive validity assessments were attempted, but the lack of any current "gold standard" measures of systems thinking and CQI project success limited our ability to make judgments about these types of validity.

Conclusions and Implications

The 20-item Systems Thinking Scale has good reliability and construct and discriminate validity. The STS is now publically available for use and a website has been established to provide information on its usefulness and encourage further refinement. The Systems Thinking Scale has the potential to contribute to the science of CQI in several ways: (1) increase our understanding of one of the mechanisms (systems thinking) by which CQI processes achieve their results; (2) increase our understanding of the human social capital available on CQI teams; and (3) improve our education efforts of future CQI team members.

II. Development of the Systems Thinking Scale

A. Overview

The development of the Systems Thinking Scale was generated over the course of three phases.

Phase I: Item generation and confirmation by expert panels

The conceptual domains of Systems Thinking were identified (see Figure 1) using a grounded theory approach in a series of electronic mail focus groups of CQI system experts. This method efficiently obtained the opinions from experts across the globe. The discussion of the panel of experts was analyzed for themes representing Systems Thinking domains and concept attributes. Questionnaire items were then developed within each domain. The experts were asked to review potential items and validate that they were appropriate indicators of the domains.

Phase II: Initial field testing for clarity and feasibility

Preliminary field testing for item clarity and feasibility of the instrument was conducted by administering the instrument to health care professionals. A project team member administered the instrument to the professional and recorded questions and comments about clarity of items, grammar, syntax, organization, appropriateness, and logical flow. The project team also recorded the time to complete the instrument, its acceptability to participants, and ease of use.

Phase III: Psychometric testing of final 20 items

The third phase consisted of extensive psychometric testing and additional feasibility of the Systems Thinking Scale. The instrument was administered to over 550 healthcare professionals and healthcare profession students over a variety of disciplines and a variety of delivery settings.

Following are details of each of these development phases.

B. Item Generation and Item Confirmation by Expert Panel

Our study team conducted an extensive literature search and completed 6 electronic mail discussions with 11 content experts and received feedback on definition, domains and test item bank (see Figures 1, 2 and 3) Experts reviewed the preliminary test item bank to assure congruence of the items with the working definition and identified dimensions of systems thinking.

Figure 1. Working definition of systems thinking and dimensions derived by expert panel

Working definition:
Systems thinking: The ability to recognize, understand, and synthesize the interactions, and interdependencies in a set of components designed for a specific purpose. This includes the ability to recognize patterns and repetitions in the interactions and an understanding of how actions and components can reinforce or counteract each other. These relationships and patterns occur at different dimensions: temporal, spatial, social, technical or cultural. It is fundamental to undertaking specific methodology or strategies to explore and redesign a set of components comprising a whole.

Figure 2. ***Theoretical Dimensions of Systems Thinking***
1) Sequence of events 2) Causal sequence 3) Multiple causations possible 4) Variation of different types (random/special) 5) Feedback 6) Interrelations of factors, patterns of relationships

Figure 3. Systems Thinking Scale initial item bank

1. I think the harder people work the better the outcomes will be.
2. I seek everyone's view of the situation.
3. I look beyond a specific event to determine the cause of the problem.
4. I think understanding how the chain of events occur is crucial.
5. I include people in my work unit to find a solution.
6. I think outcomes are random.
7. I think that lasting change relies on personal effort and motivation.
8. I think recurring patterns are more important than any one specific event.
9. I think of the problem at hand as a series of connected issues.
10. I consider the cause and effect that is occurring in a situation.
11. I consider the relationships among co-workers in the work unit.
12. I think that systems are constantly changing.
13. I propose solutions that affect the work environment, not specific individuals.
14. I focus on my first idea because it is often the best.
15. I keep in mind that proposed changes can affect the whole system.
16. The main reason for success is to get the person in charge to change.
17. I think my first impressions turn out to be very useful.
18. I think more than one or two people are needed to have success.
19. I keep the mission and purpose of the organization in mind.
20. I think small changes can produce important results.
21. I consider how multiple changes affect each other.
22. I focus primarily on the opinions of a champion in the system.
23. I think about how different employees might be affected by the improvement.
24. I think personal commitment is important in creating lasting change.
25. I try strategies that do not rely on people's memory.
26. I recognize system problems are influenced by past events.
27. I think that system-wide change is easy to accomplish.
28. I consider the past history and culture of the work unit.
29. I consider that the same action can have different effects over time, depending on the state of the system.
30. I think uncertainty and surprise are involved.

C. Initial Field Testing

We field tested the STS with healthcare professionals (see Table 1 for sample demographics). Participants commented on the logical flow, clarity of items, organization, appropriateness and grammar. Minor changes were recommended (font size, minor rewording, and the replacement of “believe” to “think”).The revised 30-item scale then underwent initial psychometric testing.

Table 1. Demographic for healthcare professionals (N=10) who field tested the STS.

Type of participant	**N(%)**	
Administrator`	4(40)	
Pharmacist	1(10)	
Physician	2(20)	
Nurses	3(30)	
	X(SD)	**Range**
Years working in healthcare	16.9(10.2)	5-34
Years working on QI project	6.0(6.4)	1-23

D. Initial Psychometric Testing

The 30-item STS was initially tested using exploratory descriptive analysis and principal axis factor analysis.

1) Exploratory Descriptive Analysis

The STS (30 items) was administered to 342 healthcare professionals (see Table 2 for demographics of the sample). The mean item scores ranged from .76 (for item 7) to 3.46 (for item 4) and several items had means greater than 3.0. There were several items that were problematic: 1, 6, 7, 16, 17, 22, 27, and 30. Four items (6, 24, 27, and 30) were excluded from all further analyses based on poor item-total correlations or poor item wording. The remaining 26 items were included in a series of exploratory factor analyses.

Table 2 Descriptive statistics of health care professionals N=342

		N (%)
Occupation	Administration/Management	58(17)
	Dietician	3(.9)
	Staff Nurse	113(33)
	Advanced Practice Nurse	20(5.8)
	Pharmacist	4(1.1)
	Therapist	17(4.9)
	Physician	89(26.0)
	Research/ Analyst	5(1.5)
	Technician	12(3.5)
	Missing	21(6.1)
Department	Bone Marrow Transplant	10(3.1)
	Cardiology	16(4.9)
	Critical Care	59(18.2)
	General Medical/Surgical Unit	98(30.2)
	Emergency Room	2(.6)
	Quality Department	15(4.6)
	Family Medicine	13(4.0)
	Pediatrics	18(5.5)
	Pharmacy	1(.3)
	Rehabilitation	21(6.6)
	Surgery	9(2.8)
	Other	55(16.9)
	Missing	8(2.5)

Table 2 (Continued)
Descriptive statistics of health care professionals N=342

	N(%)	X (SD)
Years working in Healthcare		15.6 (11.3)
0-5 years	90(26.3)	
6-15 years	99(28.9)	
16 or more years	142(41.5)	
Number of years worked on quality improvement		6.6(8.5)
Never	17(5.0)	
1 year or less	119(34.8)	
2 to 13 years	132(38.6)	
14 or more years	59(17.3)	

2) Principal Axis Factor Analysis

Construct validity was performed on the 26-item scale (See Table 1 above for sample description (Healthcare Professionals, N=342). Construct validity is the degree to which a measure performs in accordance with theoretical expectations and is the best way to assess validity for abstract constructs (Carmines & Zeller, 1979). Construct validity was assessed using Principal Axis (PA)Factor Analysis. PA Factor Analysis was used to identify domains represented in this measure and further refine the set of items that comprise the STS.

Principal axis factor analysis with oblique rotation was conducted for differing numbers of extracted factors, with a 3-factor solution appearing most useful. Twenty items loaded high and cleanly on factor 1 (ranging from .35 to .69). This factor is interpreted as Interdependencies of system components. Two items (1 and 7) loaded cleanly on a separate factor (.67 and .44) interpreted as Personal Effort Four items (14, 16, 17, and 22) loaded on a distinct 3rd factor, Reliance on authority though the loadings were not as high as for other items (.53, .40, .44, .30). Factors were distinct in that they did not correlate strongly with each other. Factors 1 and 2, however, correlated negatively (-.21) (see Appendix B).

We ran preliminary reliability analyses and the coefficient alpha for the 20-item subscale corresponding to factor 1 was .89. Coefficient alpha for the 2-item subscale corresponding to factor 2 was .55: this was reasonable given that it is a 2-item scale. Coefficient alpha for the 4-item subscale corresponding to factor 3 was .54, relatively low for a 4-item scale.

Based on these reliability analyses and factor analyses, the 20 items of what is referred to as factor 1 (system interdependencies) appeared to be the strongest performing items of the intended construct of systems thinking. The theory behind the items that loaded on what are referred to as factors 2 and 3 may be important, but these items, as worded and based on item responses from this particular sample, do not function well as part of a single overall measure of systems thinking. Experts on systems thinking seem to agree that the concepts represented by the content in the items of these other two factors are important. Thus, we have recently generated additional items for further evaluation and they are undergoing analyses.

NOTE:
The remaining analyses were performed using the 20-item STS(Appendix A).

III. Systems Thinking Scale (STS)   20 items

A. Validity

1) Discriminate Validity

Discriminate validity using the 20-item STS was tested. Discriminate validity or known-group difference validity, is confirmed when scores on an instrument are able to discriminate among groups (Carmines & Zeller, 1979). The known groups in this situation are a group of students who received systems thinking education during a 2-hour course in the medical school (Low dose; N=78) and a group of students in a15-week quality improvement course that emphasized systems thinking (High dose; N=11) and a general health professionals course (nursing pharmacology N=32) who received no education specific to systems thinking (See Table 3 for description of the sample). The STS was administered in a pretest-posttest format and validity was assessed by calculating the difference in change between the two groups. Discriminate validity was supported as the post test significantly increased in the high dose group only (see table 4 and 5). **RESULTS:** Discriminate validity was supported as the post test significantly increased in the high dose group only and the ANOVA was significant for the comparison between the high and no dose groups (see table 4 and 5).

Table 3. Demographics of student participants.

	N(%)
Type of student	
Health Professions	1(.4)
Medical	184(82.1)
Nursing	27(12.2)
Public Health	11(4.9)
Missing	1(.4)
Level of education	
Undergraduate	3(1.3)
Graduate	214(95.5)
Post-Graduate	2(.9)
Missing	5(2.2)
Student healthcare experience	
Yes	123(54.9)
no	99(44.2)
Number of years in healthcare	
1 to 2 years	64(28.6)
3 or more years	54(24.1)
Prior involvement working on QI	
Yes	59(26.3)
No	158(70.5)

Table 4. Results for Discriminate Validity. System Thinking Scale results for students receiving 3 levels of systems thinking education.			
Sample	**Intervention Dose**	**Pre intervention M (SD)**	**Post-intervention M(SD)**
Graduate entry pre-licensure nursing N=32	No intervention	61.0 (7.1)	57.3 (5.5)
1st year Medical Students N=78	Low dose intervention 2 hour class on an error case with 2 hour case study work	56.1 (7.4)	54.9 (8.6)
Graduate interprofessional students N= 11	Participated in a semester course on QI that emphasized systems thinking 15 3-hour classes	60.1(8.3)	62.0(7.4)

Table 5. ANOVA results for differences among high, low and no dose of systems thinking education.

Ttype of survey		Mean Difference	Std. Error	Sig. [a]	95% Confidence Interval for Difference	
					Lower bound	Upper Bound
Low dose	High dose	-2.865	1.486	.05	-5.814	.084
	No dose	2.077	1.390	.14	-.681	4.835
High dose	Low dose	2.865	1.486	.07	-.084	5.814
	No dose	4.942*	1.856	.01	1.259	8.624
No dose	Low dose	-2.077	1.390	.14	-4.835	.681
	High dose	-4.942*	1.856	.01	-8.624	-1.259

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least significant difference (equivalent to no adjustments).

*. The mean difference is significant at the .05 level.

2) Concurrent Criterion-Related Validity

Concurrent criterion-related validity is confirmed when scores on an instrument are correlated to a related criterion at the same point in time (Carmines & Zeller, 1979).

We sought out to find an instrument that measures continuous quality improvement (CQI) proficiency or systems thinking. We could not find an instrument that measured systems thinking so we choose the only measure identified that measures CQI proficiency- the QI Knowledge Application Tool (QIKAT). The QIKAT is a standardized written instrument to assess learner application of CQI knowledge and the integration of CQI concepts. The QIKAT consists of 3 scenarios that describe quality improvement opportunities. Participants are asked to answer a set of questions in response to the scenarios, some of which assess system/process thinking ability. The QIKAT has demonstrate inter-rater reliability (r=.55)and construct validity (Morrison et al., 2003). For our analysis, during the first week of an interdisciplinary CQI course students (N=11) were administered the STS and the QIKAT (see Table 6).

As a second concurrent-criterion-related validity test, we administered the STS to 1st year medical students (N=78)who received four hours of systems thinking education related to an error case during their block one studies. Tests of correlations of the scores of the STS and the summative evaluation questionnaire (SEQ) (item # 3 that dealt with systems thinking integration) scores were done.

RESULTS: Low correlations were found for both the QiKAT and SEQ. These low correlations could be due to a lack of a good validated measure of CQI proficiency and the subjectivity in the measurement of both the QiKAT and SEQ.

Table 6. Correlations between scores on Systems Thinking Scale (STS) and other indirect measures of systems thinking.

	Other measure of systems thinking	**Pearson Correlation**
Graduate interprofessional students N= 11	QI Knowledge Application tool (QiKAT)*	.46
1st year Medical Students N=78	SEQ Test item	.28

*QIKAT assesses learner application of QI knowledge and the integration of QI concepts. The QIKAT consists of three scenarios that describe QI opportunities. Participants are asked to answer a set of questions in response to the scenarios, some of which assess system/process thinking ability.

B. Reliability

Reliability Testing is done to ascertain if an instrument consistently measures an attribute (Nunnally & Bernstein, 1994). Two forms of reliability, internal consistency and test-retest, were obtained.

1) Internal Consistency Reliability

Internal consistency reliability was assessed using the test statistic Cronbach's alpha coefficient. This coefficient measures the internal consistency of a set of items on a measure. For these analyses, the sample of health professionals and health professions students was used (N=342). Refer to Tables 2 and 3 for demographics of this sample.
RESULT: The internal consistency of the STS (20-item) on this sample was found to be .82.

2) Test-Retest Reliability

A second type of reliability, test-retest, was assessed in which 36 participants were administered the Systems Thinking Scale at a two-week interval. See Table 7 for the demographics of the sample for this assessment.
RESULT: The STS had adequate test-retest reliability (Carmines & Zeller, 1979); the correlation between the pre and post test was .74. Mean scores are listed in Table 8.

Table 7 Sample demographics for Test-Retest N=36

		N
Type of Healthcare professional	Staff nurses Advanced practice Administrators Physicians Quality improvement professionals Health professions students	6 4 3 2 2 19
Years in health care Healthcare professional	Range	X= 24.6
Years in Quality Healthcare professional	Range	X=10.6
Experience working in healthcare Students	Range 1-4 years	50%
Experience working on QI projects		20%

Table 8 Mean score for test/retest sample

	n	Mean	Standard Deviation
STS Pretest	26	61.43	6.51
STS Posttest	26	59.08	5.70

P < .001

IV. Scoring

Systems Thinking Scale (20 Items; See Appendix A)

Scoring
Responses to the items on the Systems Thinking Scale are provided by users on a likert-type scale:
0=Never, 1=Seldom, 2=Some of the time, 3=Often, and 4=Most of the time.

Item scores are summed to provide a STS score. Scores can range from 0 – 80. There are no reverse coded items. Below are the mean scores and ranges obtained on the STS for varies categories of healthcare professionals (see Table 9).

Table 9. Mean Scores for different healthcare professionals.

Type of population	**Sample size (N)**	**Mean(SD)**	**Range**
Health care Providers	225	61.1(7.9)	40-79
Health care Providers with >5 years experience	175	61.8(8.0)	40-79
Health care Providers with >=5 years experience in QI	121	62.8(7.6)	45-79
Quality Improvement specialists	19	68.7(6.9)	54-79
All students	169	56.4(7.7)	30-76
Medical Students	82	56.1(7.5)	42-72
Nursing Students	15	61.0(7.4)	48-76
Public Health Students	8	63.1(6.3)	56-72

V. Future Work

We have recently developed new items for the two subscales of the STS that did not perform well on our initial psychometric assessment: Personal effort and Reliance on Authority. Tables 10 and 11display the new items for these two subscales. We are currently testing the STS with these new items included.

Table 10. Preliminary new items for the subscales Personal effort

New items: **Personal Effort**

1. I concentrate on the effort people put into their work.
2. I think that lasting change relies on personal effort and motivation.
3. I think people who do not get their desired results/outcomes did not work hard enough.
4. I think hard work and motivation are secondary to work process.
5. I think it is not how hard you work, but how smart you work.
6. I think how the system is organized is important to influence change than personal efforts by individuals.
7. I think that success depends on making changes beyond those of one person.

Table 11. Preliminary new items for the subscale Reliance on Authority

New items: **Reliance on Authority**

1.. I focus on my first idea because it is often the best.
2. The main reason for success is changing the person in charge.
3. I think my first impressions turn out to be very useful.
4. I focus primarily on the opinions of a champion in the system.
5. I believe initial reactions or solutions to the problem are the best.
6. I focus on the opinion of stakeholders first.
7. I think the leaders of the organization have the best ideas.
8. I think a bottom-up strategy is usually best.
9. I think people closest to the everyday work of the job should be heavily involved.
10. It is more important to think of system changes rather than what the leader wants.

VI. Contact Information Permission to use

For further information and permission to use the Systems Thinking Scale, you can contact Drs. Mary Dolansky (mary.dolansky@case.edu) or Shirley Moore (Shirley.moore@case.edu)

Or

Visit our website at fpb.case.edu/SystemsThinking

VII. Acknowledgement

Suggested Citation for the STS

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VIII. References

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Appendix A

20 item Systems Thinking Scale

Making Improvement

Instructions:

Please read each of the statements and place an "x" in the answer box that indicates frequency of agreement with the statement:

When I want to make an improvement. . .	Never	Seldom	Some of the time	Often	Most of the time
1. I seek everyone's view of the situation.					
2. I look beyond a specific event to determine the cause of the problem.					
3. I think understanding how the chain of events occur is crucial.					
4. I include people in my work unit to find a solution.					
5. I think recurring patterns are more important than any one specific event.					
6. I think of the problem at hand as a series of connected issues.					
7. I consider the cause and effect that is occurring in a situation.					
8. I consider the relationships among co-workers in the work unit.					
9. I think that systems are constantly changing.					
10. I propose solutions that affect the work environment, not specific individuals.					

When I want to make an improvement. . .	Never	Seldom	Some of the time	Often	Most of the time
11. I keep in mind that proposed changes can affect the whole system.					
12. I think more than one or two people are needed to have success.					
13. I keep the mission and purpose of the organization in mind.					
14. I think small changes can produce important results.					
15. I consider how multiple changes affect each other.					
16. I think about how different employees might be affected by the improvement.					
17. I try strategies that do not rely on people's memory.					
18. I recognize system problems are influenced by past events.					
19. I consider the past history and culture of the work unit.					
20. I consider that the same action can have different effects over time, depending on the state of the system.					

Appendix B

Table Principal Axis Factor Analysis: Factors, Eigen values, and Percentages of Variance

	Factor Loading		
Item	1	2	3
I consider the past history and culture of the work unit	.69	-.03	.14
I consider how multiple changes affect each other	.66	-.06	-.05
I think about how different employees might be affected by the improvement	.65	-.01	.06
I consider that the same action can have different effects over time, depending on the state of the system	.64	-.14	.08
I keep in mind that proposed changes can affect the whole system	.63	-.06	-.02
I consider the cause and effect that is occurring in a situation	.62	.12	-.22
I keep the mission and purpose of the organization in mind	.61	.02	.02
I propose solutions that affect the work environment, not specific individuals	.57	.10	.15
I look beyond a specific event to determine the cause of the problem	.54	.15	-.24
I recognize system problems are influenced by past events	.53	-.09	.01
I think small changes can produce important results	.52	-.20	-.06
I consider the relationships among coworkers in the work unit	.50	.02	-.09
I include people in my work unit to find a solution	.50	.31	-.07
I try strategies that do not rely on people's memory	.48	-.02	.18
I think of the problem at hand as a series of connected issues	.45	.10	-.19
I think understanding how the chain of events occur is crucial	.45	.18	-.21
I seek everyone's view of the situation	.42	.13	-.22
I think more than one or two people are needed to have success	.39	.02	.01
I think that systems are constantly changing	.36	-.07	.03
I think recurring patterns are more important than any one specific event	.35	.05	-.16
I focus on my first idea because it is often the best	.13	.53	.08
I think my first impressions turn out to be very useful	-.01	.44	.12
The main reason for success is to get the person in charge to change	.01	.40	.06
I focus primarily on the opinions of a champion in the system	-.15	.30	-.12
I think the harder people work the better the outcomes will be	.04	.15	.67
I think that lasting change relies on personal effort and motivation	-.26	.20	.44
Eigenvvalues	6.8	1.8	1.5
% of Variance	26.2	7.1	5.9