Evaluating the Performance Efficacy of Systems Thinking Tools

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Abstract

There are numerous systems thinking tools that have been introduced in the system dynamics literature, yet little is known about their efficacy in promoting performance improvements. A study was done involved fifty undergraduate business students to determine whether training in the use of systems thinking tools caused any observable performance improvement in the use of two different microworlds. The results of this exploratory research suggest that users of systems thinking tools proceed up a steep learning curve that causes a worse before better pattern of behavior. As user levels of mastery rise and the frequency of use of a given tool increases, the probability of experiencing performance improvements also increases.

Introduction

Systems thinking is a process that has been described variously as a language, a body of knowledge, a conceptual framework, and a way of understanding causal relationships and emergent properties of systems. (Checkland, 1981; Senge 1990; Cavaleri and Obloj, 1993) Goodman (1994) defines systems thinking as being "a language for communicating about complexities and interdependencies." (p. 6) Even though systems thinking has been defined in different ways, there is general consensus that suggests systems thinking praxis involves more than thinking about systems. It also relies on the use of various conceptual modeling processes, specific thinking skills, and the application of *systems thinking tools* to aid in understanding the underlying reasons for the behavior of complex systems.

Systems modeling processes enable the process of engaging in systems thinking by enabling practitioners to surface unexamined tacit assumptions for scrutiny and possible validation. The practice of systems thinking relies on the effective use of a relatively broad range of diverse thinking skills. Richmond (1993) has identified seven types of systems thinking skills that include 1) dynamic thinking, 2) closed loop thinking, 3) generic thinking, 4) structural thinking, 5) operational thinking, 6) continuum thinking, and 7) scientific thinking. Systems thinking tools are conceptual frameworks and methods of analysis for understanding relationships between systemic structures and patterns of behavior-over-time in complex systems. Systems thinking tools can be used alone or together for the purpose of garnering deeper insights into dynamic behavior (Kim, 1994).

Types of Systems Thinking Tools

Kim (1994) has identified at least ten different systems thinking tools and organized them into four general categories: 1. brainstorming tools, 2. dynamic thinking tools, 3. structural thinking tools, and computer-based tools. Included among these tools identified by Kim are: (1) Double-Q diagramming, (2) Behavior Over Time Diagramming, (3) Causal Loop Diagramming, (4) System Archetypes (5) Graphical Function Diagramming, (6) Structure-behavior pairing, (7) Policy Structure Diagramming, (8) Computer Models, (9) Management Flight Simulators, (10) Learning and Laboratories. Several other systems thinking tools have been developed in related literature. Thompson (2002) describes *causal tracing* as method for identifying causal links between system variables. Additionally, Mason and Mitroff (1981) have developed a tool, based on the work of Ackoff, known as *Surfacing and Testing Assumptions*. While this tool was not specifically designed a systems thinking tool, it serves a particularly valuable purpose for assessing the face validity of strategies and adopts of systems perspective. Mason and colleagues note, "Because the outcome of a strategy is the cumulative effect of actions taken by stakeholders during its implementation, strategic planners must identify and validate all of the assumptions being made about each stakeholder in the system." (Rowe, Mason, Dickel, and Snyder, 1989, p. 86). The five systems thinking tools that have been selected for inclusion in this study were chosen by virtue of several criteria. These are: 1) relevance to the course content, 2) compatibility with flight simulator features, and 3. learning time required to achieve proficiency in use.

Mental Models, Tools, and Performance

Despite the apparent growing use of modeling process, skills, and tools, by practitioners of systems thinking, little is known about the real capacity of these technologies to improve performance in complex systems. Further, even less is known about the relative efficacy of each of the various systems thinking tools in causing performance improvements. There are many possible explanations why there is relatively little know about the performance-enhancing potential of such systems thinking tools. The single most significant factor that has diverted attention away from evaluating systems thinking tools has been the emphasis on measuring changes in mental models. Ascertaining changes in mental models has been generally view as the starting point in determining whether systems thinking tools have had measurable effects. This would seem to be a logical starting place, since the goal of most systems thinking interventions is to enrich the mental models of those practitioners and policy-makers whose intentions are to improve the performance of a complex system. Unfortunately, this approach has proven to be difficult in practice due to the difficulty in accurately measuring changes in mental models. Some would argue that although mental models are simplified maps of reality, that mental models of most dynamic systems are still complex enough to make measurement of changes difficult or impossible. Other perspectives, such those found in the writings of philosopher Charles Sanders Peirce, argue that beliefs are generally resistant to change at all. Peirce is noted for his famous observation that it is easier for most people to lie than to change their beliefs. Even putting the question of whether foundational beliefs can be changed, the problems of defining mental models in operational terms and measuring changes in them are daunting. The lack of knowledge about how the actions of agents are influenced by mental models may be attributed to the difficulty inherent in measuring changes in their perceptions and predicting how these changes actually cause alterations in how they act upon the perceived interdependencies, causal relations, and dynamics of a system. (Cavaleri and Sterman, 1997)

Evaluating exactly how changes in mental models produce corresponding changes in practitioner decisions and subsequent system behavior has proven to be a very challenging task. A limit to research on mental models has been the lack of an operational definition that enables precise measurement. More recently, greater consensus as to the definition of the term has been established. Doyle and Ford (1999) define a mental model of a dynamic system as "a relatively enduring and accessible, but limited, internal conceptual representation of an external system (historical, existing, or projected) whose structure is analogous to the perceived structure of that system." P.17 Yet, the challenge of defining the construct in operational terms still remains and despite the apparent parsimony of this definition. Is it time to shift the focus of systems thinking research toward assessing changes in how agents use knowledge and tools that reflect their mental models, rather than to attempt to measure mental models directly?

This paper will propose a way of assessing the impact of systems thinking on performance that focuses on more narrowly on the use of tools, by agents, rather than on mental models per se. This is not to discount the importance of mental models to systems thinking, but rather to acknowledge the seeming impracticality of measuring changes in them as relate to complex systems. There is no doubt that pioneers who are researching mental models, such as Johnson-Laird (1983), Holland (1986), and Schumacher (1992) have made great strides, yet their conclusions seem more relevant to relatively simple systems and processes of reasoning. More specifically, the purpose of this research is to evaluate the extent to which the use of a given systems thinking tool contributes to improved performance in a microworld. Secondly, it is to provide an empirical basis for differentiating the performance enhancing value of the major systems thinking tools.

More generally, there is a relative dearth of knowledge about the capacity for systems thinking to improve performance. Research by Costello (2001) claims to have demonstrated that the use of a microworlds has helped students to develop a deeper understanding of supply/demand dynamics and refers to "post-testing" that was done, but it is unclear what was measured or how the research was conducted. The lack of evidence to support the efficacy of systems thinking is a problem is particularly troublesome for the field of system dynamics due to an apparent paradox. Namely, one of the central tenets of system dynamics is to emphasize the importance of understanding patterns of cause and effect. Yet, relatively few advances have been made towards evaluating the effects of systems thinking itself on performance in organizations.

Problems in Measuring the Effects of Systems Thinking

The lack of significant progress toward evaluating the impact of systems thinking on performance has its roots in the difficulties inherent both in explaining how human thought influences behavior, and how human decisions affect the behavior of complex systems. As Doyle (1997) notes, relying on participant self-reported data about cognitive changes, anecdotes, and observations tend to produce results of questionable validity. Research on systems thinking is further complicated by the fact that performance data in complex systems are usually subject to delays, ambiguities in interpretation, and subject to limited information. (Sterman, 1994) Inferring evidence of changes in patterns of performance in complex systems simply by attributing them to shifts in mental models alone also ignores the impact of knowledge and the use of tools on decision-making efficacy. Explanations of how thinking influences action and behavior in complex systems must be extended to include the respective roles played by knowledge, and the application of knowledge through the use of tools. There is a well- developed line of inquiry that explores the role of beliefs to knowledge and action that can be found in the writings of the Pragmatists philosophies espoused by Charles Sanders Peirce, John Dewey, William James, and E. A. Singer. These writers have focused to a greater degree on explaining how effective action mediates beliefs as much as how true beliefs lead to effective action. Peirce, for example, views action's purpose as being to clarify mental habits and beliefs. According to this view, true beliefs cause effective action, but also effective action serves to confirm one's beliefs. This research will focus on discerning whether changes in mental models are reflected in the effectiveness with which systems thinking tools are used. It is proposed that enrichment of mental models will lead to more robust use of systems thinking tools that will in turn lead to improved performance.

Research Design

The goal of this exploratory research was to determine the performance-enhancing effects of using each of five systems thinking tools to analyze a microworld. The research environment was an undergraduate system dynamics/systems thinking course offered to forty-six business students at medium-sized public university. Students were instructed on the use of the five systems thinking tools and asked to apply them while playing a microworld known as Luigi's Pizza. Students prepared for the exercise by reading books on systems thinking as well as listening to lectures on the application of systems thinking tools. Students received a total of fifteen hours of educational experiences in preparation for their participation in this experiment. The microworld used is that of a single retail pizza restaurant establishment. The underlying system dynamics model was designed using Vensim. Students made decisions that set the amount of money spent on advertising, amount of cheese place on each pizza, determined the number of free giveaways of pizza that would be used for promotional purposes, and established the size of their free customer delivery zone. The Luigi's Pizza microworld allows students to play for up to sixty months. It provides the following features: 1. behavior over time graphs, 2. causal tracing capabilities, 3. causal loop diagrams, and 4. causal tree diagrams.

Hypothesis #1

Systems thinking tools that are perceived as being more valuable when used more often will lead to relatively better performance.

Hypothesis #2

Systems thinking tools that are perceived as being more valuable when used more a greater portion of the total time devoted to playing the microworld will lead to relatively better performance.

Hypothesis #3

Systems thinking tools that are perceived as being more valuable when used more often, and a greater portion of the total time devoted to playing the microworld will lead to relatively better performance.

Results and Findings

Data were obtained from forty-six students. For each of five systems thinking tools, each student was asked to rate the following:

a. <u>The overall value of each systems thinking tool</u>.

   Specifically, they were asked, 'How valuable was the tool in enabling me to improve my performance for the 'cash balance' in the Luigi's Pizza microworld?'

b. <u>Frequency of use of each systems thinking tool</u>.

   Specifically, they were asked, 'How often did I use each tool relative to all of the other systems thinking tools?'

c. Time of use for each tool.

Specifically, they were asked, ‘What percentage of the total time that I spent using systems thinking tools did I devote to using each tool?’

Each of the questions were presented to the participant on a scale represented by 100 points in order to represent an equivalent range of potential values. That is, it was assumed that the student participant would be able to respond easier when each question appeared to have the same numbering scheme.

For each participant the data were analyzed separately for each systems thinking tool. An analysis was also conducted combining all the tools, given that the objective of this study was to determine if a tool was valued and used frequently and led to performance. There was no a priori prediction in this study regarding the merits of any particular tool, nor was it assumed that there was any tool that would definitely lead to significant performance improvements.

Descriptive Statistics

The mean and standard deviation was determined for each systems thinking tool. Tables 1 through 5 present the means and standard deviations for each of the tools.

Table 1. Causal Loop Diagramming Descriptive Statistics

	Value	Frequency	Total Time
Mean	64.630435	58.36957	31.2
St. Dev.	27.717911	26.85795	14.16

Table 2. Behavior-Over-Time Descriptive Statistics

	Value	Frequency	Total Time
Mean	63.17	56.30435	22.93
St. Dev.	28.43	28.64408	12.37

Table 3. Structure-Behavior Pairs Descriptive Statistics

	Value	Frequency	Total Time
Mean	45.54	40.26087	12.39
St. Dev.	26.86	24.16557	6.137

Table 4. Surfacing and Testing Assumptions Descriptive Statistics

	Value	Frequency	Total Time
Mean	44.35	39.28261	15.11
St. Dev.	22.92	22.55528	9.583

Table 5. Causal Tracing Descriptive Statistics

	Value	Frequency	Total Time
Mean	60.11	54.65217	20.15
St. Dev.	27.27	26.36683	8.917

Relationships Among Variables

To determine the relationship between respondent's perception of value, as well as the frequency and total time variables, the variables were correlated with the 'cash balance' obtained in the microworld at the end of sixty months. Cash balance is a cumulative amount that is calculated by subtracting costs from revenues. The following tables present the data for each tool, the inter-correlations as well as the correlation with the cash balance performance. At a p = .05, an r = .29 is significant.

Table 6. Causal Loop Diagramming: Correlations among Value, Frequency, Total Time and Cash Balance

	Value	*Frequency*	*Total Time*	*Cash Balance*
Value	1			
Frequency	0.855887047	1		

Total Time	0.38911126	0.333437909	1	
Cash Balance	-0.358175158	-0.284647495	-0.226197002	1
N = 46	alpha = .05, df = 44, r = .29			

Table 7. Behavior Over Time: Correlations among Value, Frequency, Total Time and Cash Balance

	Value	*Frequency*	*Total Time*	*Cash Balance*
Value	1			
Frequency	0.865249322	1		
Total Time	0.372920003	0.284957482	1	
Cash Balance	-0.174753642	-0.090004794	0.005131897	1
N = 46	alpha = .05, df = 44, r = .29			

Table 8. Structure-Behavior Pairs: Correlations among Value, Frequency, Total Time and Cash Balance

	Value	*Frequency*	*Total Time*	*Cash Balance*
Value	1			
Frequency	0.780753691	1		
Total Time	-0.173207486	0.067621826	1	
Cash Balance	-0.304980373	-0.080622373	0.074721468	1
N = 46	alpha = .05, df = 44, r = .29			

Table 9. Surfacing Assumptions: Correlations among Value, Frequency, Total Time and Cash Balance

	Value	*Frequency*	*Total Time*	*Cash Balance*
Value	1			
Frequency	0.766305879	1		
Total Time	-0.109466829	0.179774728	1	
Cash Balance	-0.009106381	-0.101379361	0.077142133	1
N = 46	alpha = .05, df = 44, r = .29			

Table 10. Causal Tracing: Correlations among Value, Frequency, Total Time and Cash Balance

	Value	*Frequency*	*Total Time*	*Cash Balance*
Value	1			
Frequency	0.898668358	1		

Total Time	0.26080588	0.357039782	1	
Cash Balance	-0.229283173	-0.178840952	0.011434278	1
N = 46	alpha = .05, df = 44, r = .29			

To test Hypothesis 3, multiple correlations were conducted. Using the cash balance as the criterion, the three variables were used. The following tables present the data, separately, for each tool. As indicated in the tables, no F test is significant.

Table 11. Multiple Correlation using Causal Loop Diagramming

Regression Statistics	
Multiple R	0.372793641
R Square	0.138975099
Adjusted R Square	0.07747332
Standard Error	103829.656
Observations	46

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	73082500807	24360833602	2.259692348	0.095447102
Residual	42	4.52785E+11	10780597465		
Total	45	5.25868E+11			

Table 12. Multiple Correlation using Behavior Over Time

Regression Statistics	
Multiple R	0.213168563
R Square	0.045440836
Adjusted R Square	0.001042736
Standard Error	108045.1812
Observations	46

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*

Regression	2	23895863299	11947931649	1.023486043	0.367926696
Residual	43	5.01972E+11	11673761187		
Total	45	5.25868E+11			

Table 13. Multiple Correlation using Structure-Behavior Assumptions

Regression Statistics	
Multiple R	0.400871361
R Square	0.160697848
Adjusted R Square	0.100747694
Standard Error	102511.5329
Observations	46

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	84505790647	2.82E+10	2.681	0.05
Residual	42	4.41362E+11	1.05E+10		
Total	45	5.25868E+11			

Table 14. Multiple Correlation using Surfacing Assumptions

Regression Statistics	
Multiple R	0.210681852
R Square	0.044386843
Adjusted R Square	-0.02387124
Standard Error	109384.2062
Observations	46

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	23341602248	7.78E+09	0.65	0.587
Residual	42	5.02526E+11	1.2E+10		
Total	45	5.25868E+11			

Table 15. Multiple Correlation using Causal Tracing

Regression Statistics	
Multiple R	0.229283173
R Square	0.052570773
Adjusted R Square	0.031038291
Standard Error	106410.689
Observations	46

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*

Regression	1	27645266130	27645266130	2.441463662	0.125330528
Residual	44	4.98222E+11	11323234732		
Total	45	5.25868E+11			

Analysis and Discussion

The data do not support the hypotheses. The data do indicate that for each systems thinking tool, a significant positive relationship exists between the Perceived Value of the tool and the frequency of its use. That is, when the student valued the tool as expecting it would help toward improving performance, they used the tool more frequently. For the Causal Loop Diagramming and Behavior Over Time tools, there was a significant positive correlation between the Perceived Value of the tool and the Total amount of time devoted to its use. For the Causal Loop Diagramming, the Behavior Over Time, and the Causal Tracing tools, there was a positive significant correlation between Frequency of Use, or the number of times used, and the Total time of use. It is not known to what extent the value perception is leading the students to use the tools more frequently. Perhaps students became comfortable with the tool and continued to use it because of their comfort more than its value. For the Causal Loop Diagramming tool and the Structure-Behavior Pairs tool, there were significant negative correlations obtained between the Perceived Value and the obtained Cash Balance. The multiple regression analyses provided no significant results. As can be seen in the tables in the R square and the adjusted R square, which indicate the amount of variance that the variables contribute, that the variance is meaninglessly low.

Evaluating A Second Microworld: B & B Enterprises

The same questionnaire was subsequently used to assess changes in the performance of that sample cohort using a different microworld. Six weeks after the initial evaluation of Luigi's Pizza the same type of evaluation was done for the B & B Enterprises microworld. The sample student cohort played the B&B Enterprises microworld for five weeks prior to the assessment.

Analysis

As with the other microworld, the data for the B and B simulation indicate that a significant positive relationship exists between the Perceived Value of the systems thinking tools and the frequency of their use. It is interesting to note that while these results did yield statistical significance, but for most of the tools used in the research, the actual absolute value, and the absolute frequency of use was lower for the B & B microworld. There was a significant positive correlation between the frequency of use and the total time, in terms of percentage, only for the Causal Loop and Behavior Over Time tools. There were significant positive correlations between accumulated net profits and the frequency of use for the Behavior Over Time, Structure-Behavior Pairs and the Causal Tracing tools. Thus, for these three tools, as the sampled students used these tools more frequently they were more likely to obtain higher net profits. This finding is different from the first microworld, Luigi's Pizza, where there were negative and non-significant relationships with the criterion.

It is interesting that Perceived Value is correlated to frequency of use for each technique. Perhaps this reflects a *threshold phenomenon*, in that the participant must see some value, initially, in a systems thinking tool, and this will subsequently lead its more frequent use. In this study, while the relationships were consistent, the absolute values decreased from the initial microworld, Luigi's Pizza, to the latter microworld. Perhaps, these observed effect reflects a learning curve issue involved with the use of the systems thinking tools, or perhaps is involves a learning effect or other intrinsic characteristics of the two microworlds that were used for this research. In either case, further research is warranted. For example, would similar results have been obtained if the two microworlds had been reversed chronologically with B & B being used first? Or are there time delays that play a major role in those learning processes characterized 'gestation periods' between training and seeing the benefits of the training in performance.

The multiple correlations indicate that the Behavior Over Time technique yielded a significant F. While not significant, the Structure-Behavior Assumptions and Surfacing Assumptions were close to the .05 level. The Behavior Over Time had an R = .536, with an R^2 = .287. Thus, 28.7% of the variance can be predicted by the regression equation. Upon further analysis of Tables 16-27, it is seen that Value and Frequency have significant t tests for the coefficients, indicating they are the two critical contributing variables. It is also interesting that the Value coefficient is negative and the Frequency highly significant and positive. Thus, it appears, as mentioned above, that the Value may be the initial determinant, almost like a moderating variable, and it will lead to the frequency of use which is subsequently related to the criterion.

Descriptive Statistics

Table 16 Causal Loop Diagramming

	Value	Frequency	Total Time
Mean	61.56	59.38	41.09
St. Dev.	28.47	27.29	16.54

Table 17 Behavior Over Time

	Value	Frequency	Total Time
Mean	45.41	39.22	14
St. Dev.	35.22	32.26	7.19

Table 18 Structure-Behavior Assumptions

	Value	Frequency	Total Time
Mean	42.47	35.78	14.13
St. Dev.	33.16	29.38	7.93

Table 19 Surfacing and Testing Assumptions

	Value	Frequency	Total Time
Mean	32.28	28.28	10.47
St. Dev.	26.19	26.14	6

Table 20 Causal Tracing

	Value	Frequency	Total Time
Mean	48.5	40.78	20
St. Dev.	29.97	28.12	9.76

Table 21
Relationships Among Variables

Causal Loop Diagramming

	Value	*Frequency*	*Total Time*	*Net Profit*
Value	1			
Frequency	0.7684294	1		
Total Time	0.2000016	0.426631	1	
Net Profit	0.1238737	0.12975	-0.18635	1
N = 32	alpha = .05	, df = 30	r = .35	

Behavior-Time

	Value	*Frequency*	*Total Time*	*Net Profit*
Value	1			
Frequency	0.9044763	1		
Total Time	0.4449695	0.433336	1	
Net Profit	0.2331959	0.415187	0.083498	1
N = 32	alpha = .05	, df = 30	r = .35	

Structure-Behavior Pairs

	Value	Frequency	Total Time	Net Profit
Value	1			
Frequency	0.7882808	1		
Total Time	0.2166757	0.3298	1	
Net Profit	0.1836114	0.378526	0.333093	1
N = 32	alpha = .05	, df = 30	r = .35	

Surfacing and Testing Assumptions

	Value	Frequency	Total Time	Net Profit
Value	1			
Frequency	0.8359696	1		
Total Time	0.14476	0.195388	1	
Net Profit	0.0945001	0.333981	-0.01709	1
N = 32	alpha = .05	, df = 30	r = .35	

Causal Tracing

	Value	Frequency	Total Time	Net Profit
Value	1			
Frequency	0.79741	1		
Total Time	0.1390053	0.179361	1	
Net Profit	0.2124017	0.369244	0.008241	1
N = 32	alpha = .05	, df = 30	r = .35	

Table 22
Multiple Correlations

Causal Loop Diagramming
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.297876
R Square	0.0887301
Adjusted R Square	-0.008906
Standard Error	580724736
Observations	32

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	9.19E+17	3.06E+17	0.908784	0.449296822

Residual	28	9.44E+18	3.37E+17		
Total	31	1.04E+19			

Table 23
Behavior Over Time
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.5362124
R Square	0.2875237
Adjusted R Square	0.211187
Standard Error	513490032
Observations	32

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	2.98E+18	9.93E+17	3.766518	0.021743371
Residual	28	7.38E+18	2.64E+17		
Total	31	1.04E+19			

Table 24
Structure-Behavior Assumptions
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.4701443
R Square	0.2210356
Adjusted R Square	0.1375752
Standard Error	536915092
Observations	32

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	2.29E+18	7.63E+17	2.648387	0.068333618
Residual	28	8.07E+18	2.88E+17		
Total	31	1.04E+19			

Table 25
Surfacing & Testing Assumptions

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.4836994

R Square	0.2339651
Adjusted R Square	0.15189
Standard Error	532440508
Observations	32

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	2.42E+18	8.08E+17	2.85062	0.055262514
Residual	28	7.94E+18	2.83E+17		
Total	31	1.04E+19			

Table 26
Causal Tracing

Regression Statistics	
Multiple R	0.3980035
R Square	0.1584068
Adjusted R Square	0.0682361
Standard Error	558081880
Observations	32

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	1.64E+18	5.47E+17	1.756744	0.178312303
Residual	28	8.72E+18	3.11E+17		
Total	31	1.04E+19			

Table 27
Behavior Over Time
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.5362124
R Square	0.2875237
Adjusted R Square	0.211187
Standard Error	513490032
Observations	32

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	2.98E+18	9.93E+17	3.766518	0.021743371
Residual	28	7.38E+18	2.64E+17		
Total	31	1.04E+19			

	Coefficients	*Standard Error*	*t Stat*	*P-value*

Intercept	1.265E+09	2.06E+08	6.145448	1.24E-06
Value	-12514860	6199377	-2.01873	0.053185
Frequency	20334708	6725276	3.023624	0.005298
Total Time	-5544758	14372626	-0.38579	0.702571

Discussion

Luigi's Pizza Microworld

In reviewing the results, the hypotheses are not supported by the data obtained from the Luigi's Pizza microworld. It is intriguing that the correlations with cash balance were negative, particularly the perceived value variable. It was hypothesized that the higher the perceived value would also lead to the tool's more frequent use as well as contribute to its overall total time used. While the students do use the tools they value most frequently, it is the step leading to performance that becomes the puzzle and will lead to further research. In other words, there might be intervening variables that exist between the total amount of time that the systems thinking tools are being utilized and the advent and conclusion of performance. Since there is a time factor that occurs, it will become critical to learn the thinking and processing that students go through.

Informal discussions with a limited number of students indicate that their level of mastery of the tools was insufficient to provide a salutary effect on performance. In fact, some students volunteered that they found the application of the tools to the microworld to be a significant complicating factor they sought to avoid when possible. Other students volunteered that the cash balance performance was actually better when they did not use the tools as the use of tools caused them to try strategies they felt did not have face validity.

If there are intervening and time factors that become involved between the use of the systems thinking tools and performance, there are significant ramifications and signals directed toward educators and trainers in organizations. It is assumed that when individuals learn the theory and obtain practice with the systems thinking tools that performance should follow. The data in this study indicates that that did not occur. Thus, future research must extend and reassess the current findings, and then identify and study those variable that intervene between the use of the systems thinking tools and the obtained performance. That will eventually lead researchers and practitioners toward more effective use of system thinking tools for improved organizational performance.

B & B Enterprises

Based on the data from B& B Enterprises, it is concluded that time is a critical factor in utilizing systems thinking tools in microworlds. There appear to be significant time delays between cause and effect from training in the use of systems thinking tools to the time when its effects are seen in performance improvements. This view holds that is takes relatively longer amounts of time to see the value of using any systems thinking tool, and the Perceived Value of any tool is significantly related to its frequency of use. Specifically, it is only the frequency of use for the Behavior Over Time, Structure-Behavior Pairs, and Causal Tracing tools that were significantly related to performance on accumulated net profits. In creating a regression analysis, Behavior Over Time analysis is the only tool that yielded a significant R, and the Perceived Value and frequency of use were the two significant contributing coefficients. While frequency of use is significantly related to net profit, in some instances, it is interesting from a research, and practical, perspective, that total time of use is not related to net profit. Thus, it is the number of times the tool is used that is important and not the total percent of the tool's use in terms of time. Certainly this study may have raised more questions than it answered. There is a definite need for a continuation of this line of research as it has tremendous implications for systems thinking research, as well as practical implications regarding the use of and the timing of the training, as well as expectations for practice times.

Conclusions

Since this is exploratory research, there are few hard and fast conclusions that can be drawn from this study. The primary value of the research is that it surfaces several key issues to define future research on the use of systems thinking tools. None of the hypothesis were confirmed by the presence of overwhelming evidence, there is significant evidence to support the systems primary hypothesis on a limited basis, namely that those systems thinking tools that are perceived as being more valuable when used more often will lead to relatively better performance. However, the supportive evidence is only true for using the Behavior Over Time tool. We really cannot say that those with higher perceived values are better for a few reasons. First of all, the perceived value of the tools is not related to net profits – however, it is clearly related to frequency of use. However, this effect exists solely in the only multiple R that was significant, frequency of use had the highest significance.

Our preliminary research suggests that the effects of training in the use of systems thinking tools generally have relatively long time periods of practice required before beneficial effects are recognized. Secondly, there is significant evidence that as users master certain tools and develop sufficient comfort to use them relatively often, then, a potential performance-enhancing effect becomes more probable. Finally, like many interventions in complex systems there is reason to believe that there is a "worse before better" phenomena in which training in the use of systems thinking tools may actually lead to performance decay prior to the attainment of a sufficient level of mastery of any given systems thinking tool.

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