Abstract Title Page
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Title: Structural Equation Modeling of Knowledge Content Improvement using Inquiry Based Instruction

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Abstract Body

Limit 4 pages single-spaced.

Background / Context:

Description of prior research and its intellectual context.

The U.S. began a new national standards movement in the area of K-12 science education curriculum reform in the 1980s known as “Science for All” to develop a population that is literate in economic and democratic agendas for a global market focused on science, technology, engineering, and mathematics (STEM) (Duschl, 2008). The National Research Council (NRC) report, *Taking Science to School: Learning and Teaching Science in Grades K-8* (TSTS; NRC, 2007b) described shortages in attracting students to science learning and careers, and of science teachers (particularly women and minorities). More recently, researchers have focused on science reform that incorporates a cultural imperative in the teaching of science (Driver, Leach, Millar, & Scott, 1996; Millar, 2006; Osborne, Duschl, & Fairbrother, 2002). The sister NRC report, *Rising above the Gathering Storm* (RAGS, NRC, 2007a), describes four areas of needed proficiency for science students of how to: generate and evaluate scientific evidence and explanations; know, use, and interpret scientific explanations of the natural world; understand the nature and development of scientific knowledge; and participate productively in scientific practices and discourse. To this end, pedagogical skills in science education have moved from teaching students how to memorize what they need to know from science textbooks to developing an understanding of the knowledge-building process by learning how to develop explanations and predictions about our world.

A key element in science education is establishing and maintaining linkages between teachers and researchers that can eventuate in enhanced student outcomes. Determining when and where a new educational program or intervention results in an enhanced outcome can be sensitive to many different forces that the researcher must carefully manage. The two NRC reports encourage changes in pedagogy and approaches better suited to the evolving technological world. As members of society are expected to process information that is updated constantly and rapidly, it is critical to understand how ideas are developed and processed. Research in abstract reasoning teaches us that infants learn causal inference and differentiation of animate and inanimate objects, demonstrating that the learning ability of even the youngest children permits them to engage in complex decision making (Gelman & Brenneman, 2004; Mertz, 2004; Spelke, 2000). To do this, students require abstract deductive and inductive reasoning skills, including the ability to view with an open mind and a willingness to be aware of the world (Critical Thinking Co., 2011).

Purpose / Objective / Research Question / Focus of Study:

Description of the focus of the research.

The target of inquiry-based approach is to increase cognitive abilities such as critical thinking. However, students, teachers, and schools are evaluated based on content student knowledge. Statistical modeling choices affect the ability to determine the efficacy of the intervention and the ability to identify those students who receive the greatest and least benefit from the intervention. As it is imperative to determine how an increase in cognitive abilities corresponds to an increase in content across different demographics and learning abilities, the effect of some of the statistical modeling choices were investigated. Student’s progress on the Iowa Test of

Basic Skills (ITBS) was modeled over two years of implementation of the inquiry-based learning approach. A control group of students not receiving the SWH learning approach was used for comparison.

Setting:

Description of the research location.

The study was conducted with Iowa elementary school students, in grades 3-6, with 24 school buildings randomly assigned to treatment and 24 to control. A description of the SWH study by letter, followed by an in-person meeting, was completed in the summer of 2009 with school district superintendents in Iowa to obtain permission for participation by elementary school buildings in the study. After obtaining consent from the district superintendents, a total of 48 schools were recruited into the study.

Population / Participants / Subjects:

Description of the participants in the study: who, how many, key features, or characteristics.

The population is students in either 3rd or 4th grade during the 2010-11 academic school years in the 48 schools. There were a total of 2,341 3rd grade students and 2,372 4th grade students enrolled in these schools during this school year. The 48 schools are located in both urban and rural locations across Iowa. All 48 schools have remained for the duration of the study, but some students couldn't participate if they were absent on the day of the exam.

Intervention / Program / Practice:

Description of the intervention, program, or practice, including details of administration and duration.

All teachers from schools that were randomized to the intervention group were trained in the SWH technique during the summer of 2009 at workshops held at four geographic regions of Iowa. This training took part over three days and included specific training on the SWH approach including how to foster argumentation and science inquiry skills for students in the classroom. Teachers foster cooperative and individual learning by requiring student groups to examine science problems and think of solutions through both inter and intra group discourse. In addition, students learn to write down discussion ideas and why they may or may not work, form their own hypothesis and test it, assisting them in science, math and English writing. All 48 selected schools currently remain in the study.

Research Design:

Description of the research design.

A cluster randomized experimental design was employed, with random assignment of participating elementary school buildings to SWH treatment or control condition. Once recruitment of buildings was completed, blocks were formed for the purposes of randomization. Blocks were either districts with multiple buildings or districts that were similar in enrollment based on percentage of students on free and reduced lunch or certified enrollment. Two exceptions to this randomization strategy were as follows: (1) two religious schools of comparable size were blocked together, and the other religious school, of very small size, was paired with another school of very small size; and (2) 10 schools not randomized initially because their data arrived later were randomized into districts as we received them.

Data Collection and Analysis:
Description of the methods for collecting and analyzing data.

Iowa Test of Basic Skills (ITBS) student scores were obtained for all students from the years immediately prior to the start of the SWH study. These ITBS scores included all composite scores and a subgroup score in science as well as demographic information about individual students. Four structural equation models were created for this analysis using MPlus software. The first model used all the students and the remaining three models used three mutually exclusive subsets of students (special education, gifted and talented, and traditional students) that together composed all the students. Structural equation models were developed in each case to analyze students standardized tests scores in math, reading and science content. The models incorporated demographic variables (Asian, Black, Hispanic), learning indicator variables (English Language Learner, Free and Reduced Lunch, Gifted and Talented, Special Education), time variables (Semesters of exposure to SWH, semester in which exam was administered), and two latent variables ("Overall" test taking ability and "Change" in knowledge and aptitude over the time period). Path diagrams of all four SEM models analyzed can be seen in figures 1-4. The path structure varies slightly across the models; the differences can be most easily seen in Table 1.

Findings / Results:
Description of the main findings with specific details.

Analyzing the mutually exclusive subgroups reveals some important findings that were masked by when all the students were analyzed simultaneously. The effect of the number of semesters of SWH exposure on the change in the math score for special education students is 0.116 which is nearly double the 0.060 estimated for traditional students. In contrast, the same effect for the gifted and talented students is -0.040. Further, the estimated path coefficients from the variable 'change' to the science and math score improvement variables is much larger for the special education students than in any of the other models. In the special education model, both of these path coefficients were estimated to be greater than 1.0 at 1.119 and 1.185 respectively. In the other three models these path coefficients were less than 1.0. This indicates that the special education students are benefitting from prolonged exposure to the SWH curriculum, particularly in math and science.

A number of the paths originating from demographic and learning variables were significant in the model for all the students, but they were not important for all subsets of the students. The path originating from the black student variable going to overall test ability was important for all students and the special education subset. However, this path was not important for traditional and gifted and talented students. The path from Hispanic students to overall testing ability also was not important for gifted and talented students while being important for the other two subsets and the model with all students. The path from Asian students to the Change in knowledge variable is important for all models except the special education model. The path from black student to the change variable has some substantial differences across the models. The path is not included in the gifted and talented model. In the traditional student model it is -

0.411 which is more than 10 times larger than in the all students model where the estimate is -0.036.

Conclusions:

Description of conclusions, recommendations, and limitations based on findings.

Structural equations modeling of student test scores in reading, math and science content were created. Modeling mutually exclusive subsets of the data provided for results, that in some cases, were substantially different from a structural equation model created using all of the student data. The separate models identified that the special education students have the greatest improvement in their mathematics test scores with increased exposure to the science writing heuristic. Traditional student's math scores also benefit from the science writing heuristic learning approach. However, this does not appear to be the case for gifted and talented students.

The science writing heuristic targets critical thinking and cognitive abilities. It is not surprising that the largest treatment path coefficients are seen for the treatment to math score improvement paths. While the science writing heuristic is implemented as a learning approach to teaching science, the approach focuses on cognitive development over content. As the science test scores used in the model are measuring content knowledge, the small coefficients for the paths from the treatment to the science are not surprising. The coefficients for the paths from the treatment to the reading scores were also very small for all the models.

Appendices

Not included in page count.

Appendix A. References

References are to be in APA version 6 format.

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Sawada, D., Piburn, M., Judson, E., Turley, J., Falconer, K., Benford, R., & Bloom, I. (2002). Measuring reform practices in science and mathematics classrooms: The Reformed Teaching Observation Protocol. *School Science and Mathematics, 102*(6), 245-253.

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Appendix B. Tables and Figures

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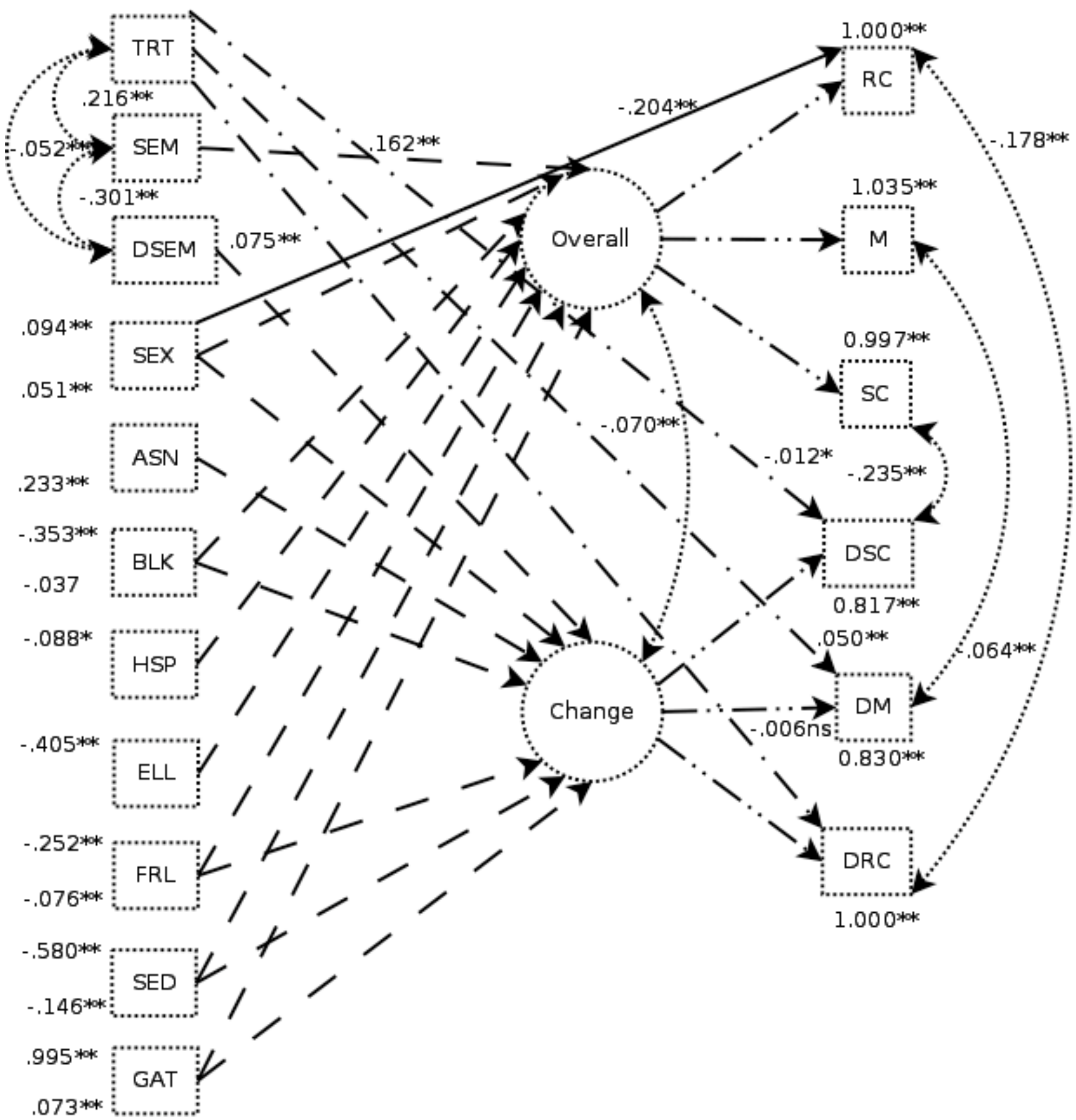
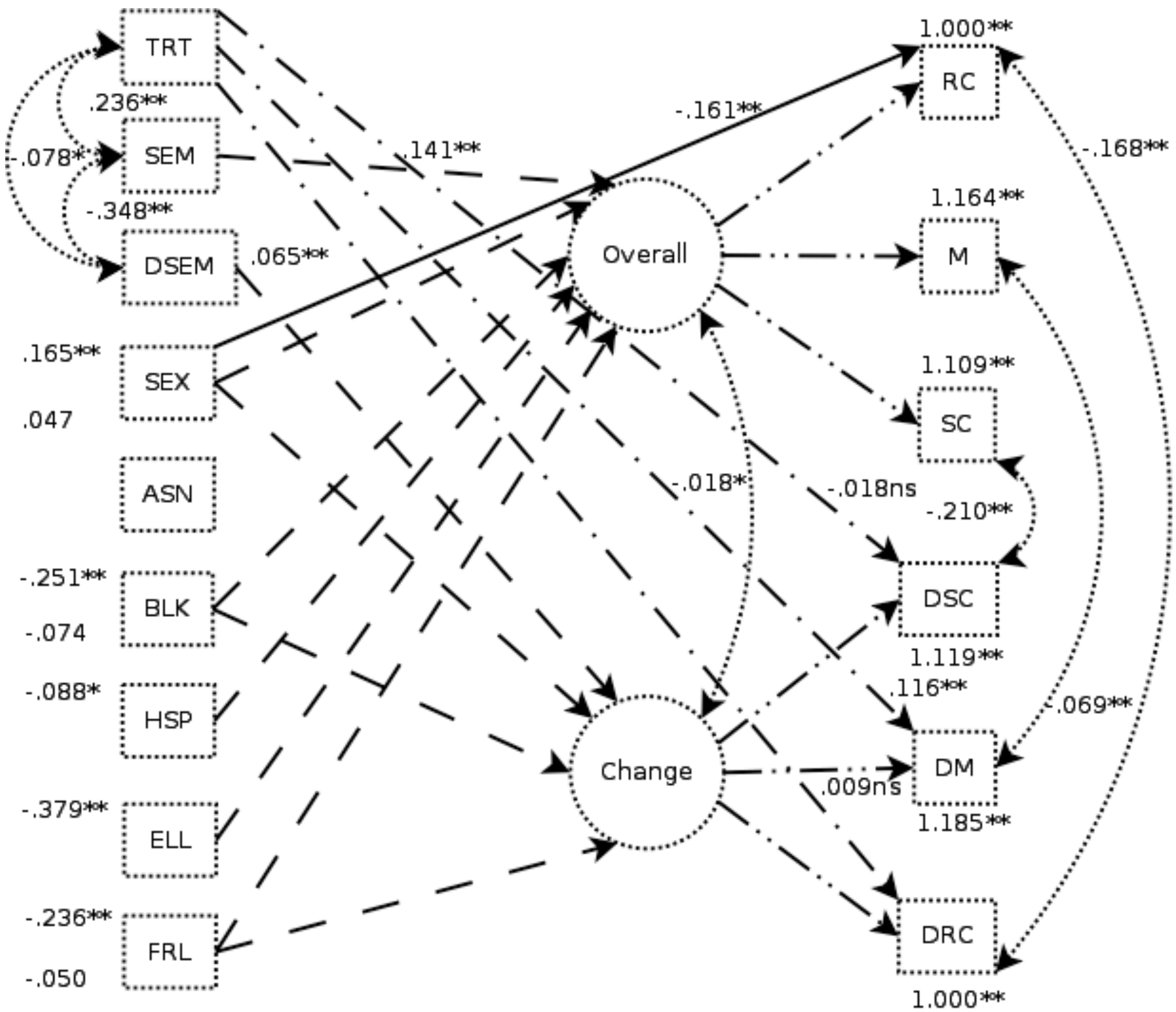
Figure 1: All Students individual effects.



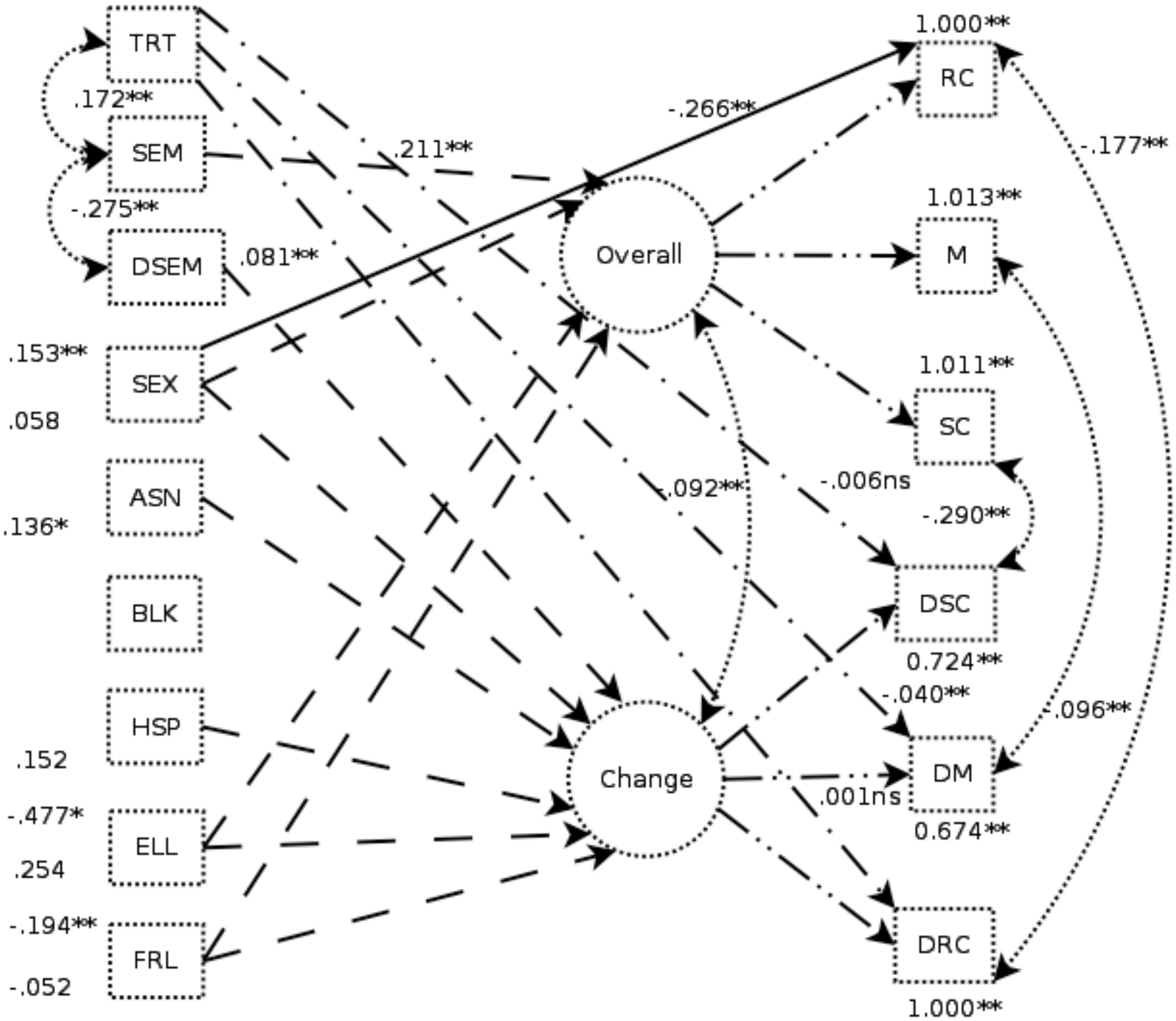
RMSEA	0.041	Chi Square Value	560.322
CFI	0.966	df	76
TLI	0.964		

Figure 2: Special Education Students Individual Effects



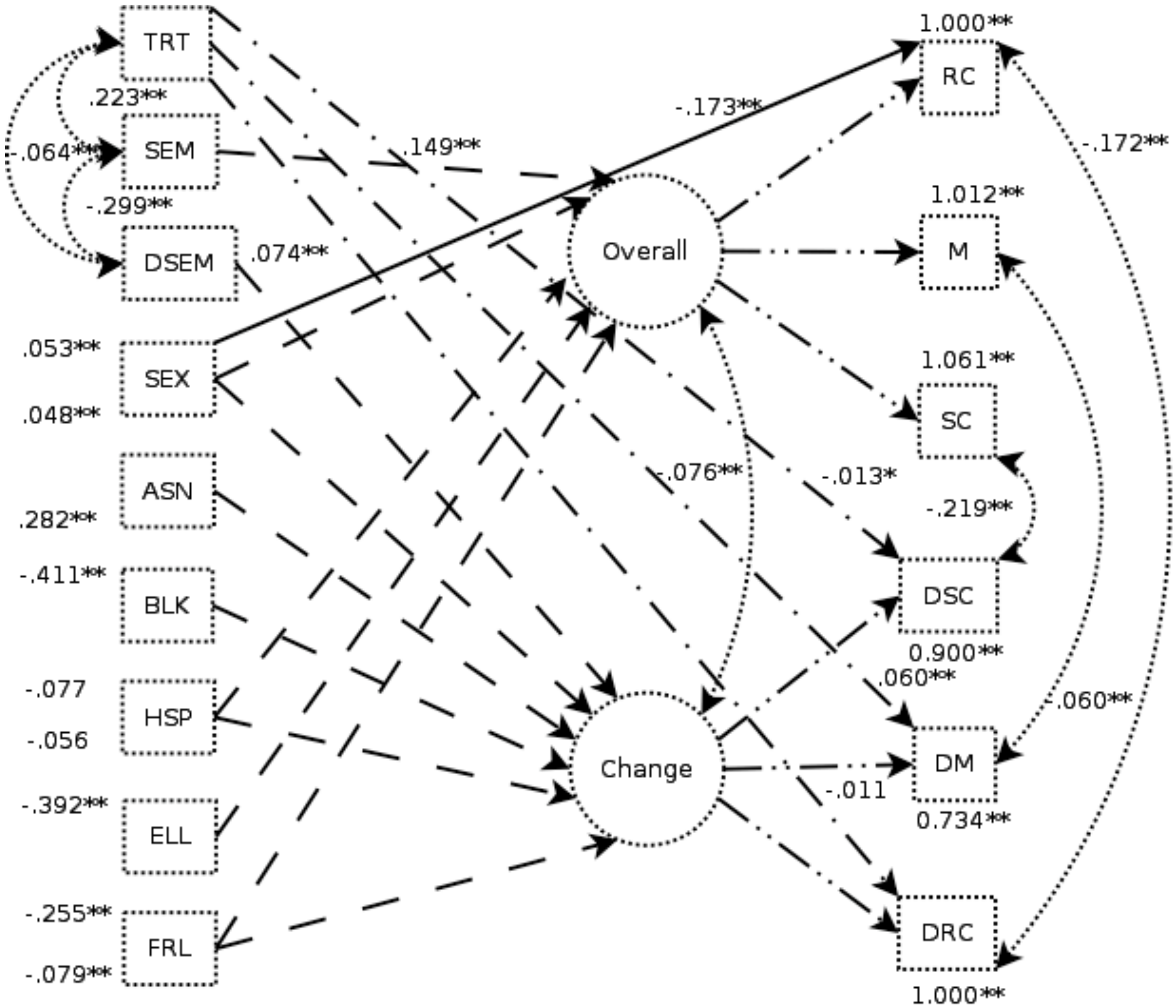
RMSEA	0.028	Chi Square Value	74.940
CFI	0.985	df	54
TLI	0.982		

Figure 3: Gifted and Talented Students Individual Effects



RMSEA	0.026	Chi Square Value	76.553
CFI	0.986	df	54
TLI	0.984		

Figure 4: Traditional Students Individual Effects



RMSEA	0.039	Chi Square Value	316.002
CFI	0.968	df	62
TLI	0.964		

Table 1: Parameter estimates from the SEM models.

Model	All Students	Special Education	Gifted and Talented	Traditional
Overall				
SEM	0.162**	0.141**	0.211**	0.149**
SEX	0.094**	0.165**	0.153**	0.053**
BLK	-0.353**	-0.251**	-	-
HSP	-0.088*	-0.088*	-	-0.077
ELL	-0.405**	-0.379**	-0.477*	-0.392**
FRL	-0.252**	-0.236**	-0.194**	-0.255**
SED	-0.580**	-	-	-
GAT	0.995**	-	-	-
RC	1.000**	1.000**	1.000**	1.000**
M	1.035**	1.164**	1.013**	1.012**
SC	0.997**	1.109**	1.011**	1.061**
Change				
DSEM	0.075**	0.065**	0.081**	0.074**
SEX	0.051**	0.047	0.058	0.048**
ASN	0.233**	-	0.136*	0.282**
BLK	-0.037	-0.074	-	-0.411**
HSP	-	-	0.152	-0.056
ELL	-	-	0.254	-
FRL	-0.076**	-0.050	-0.052	-0.079**
SED	-0.146**	-	-	-
GAT	0.073**	-	-	-
DSC	0.817**	1.119**	0.724**	0.900**
DM	0.830**	1.185**	0.674**	0.734**
DRC	1.000**	1.000**	1.000**	1.000**
Direct				
TRT - DSC	-0.012*	-0.018	-0.006	-0.013*
TRT - DM	0.050**	0.116**	-0.040**	0.060**
TRT -DRC	-0.006	0.009	0.001	-0.011
SEX - RC	-0.204**	-0.161**	-0.266**	-0.173**
Variances				
Overall-Change	-0.070**	-0.018*	-0.092**	-0.076**
RC - DRC	-0.178**	-0.168**	-0.177**	-0.172**
M-DM	-0.064**	-0.069**	-0.096**	-0.060**
SC-DSC	-0.235**	-0.210**	-0.290**	-0.219**
TRT-SEM	0.216**	0.236**	0.172**	0.223**
TRT-DSEM	-0.052**	-0.078*	-	-0.064**
SEM-DSEM	-0.301**	-0.348**	-0.275**	-0.299**

** $p<0.001$ *$0.01 <p < 0.001$