# *Supplementary Material*

**Student Assessment of Teaching as a Source of Information about Aspects of Teaching Quality in Multiple Subject Domains: An Application of Multilevel Bifactor Structural Equation Modeling**

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**M*plus* sample code of the single- and multilevel bifactor structural equation models**

1. Single-level bifactor structural equation model of student assessments

TITLE: Single-level BFSEM of student assessments

DATA: FILE IS timss2011.dat;

VARIABLE: NAMES ARE IDCLASS IDSTUD HOUWGT FIN NOR RDEXP RDEASY RDINT MAEXP MAEASY MAINT SCEXP SCEASY SCINT;

 ! Item labeling:

 ! RD = Reading, MAT = Mathematics, SC = Science

 ! EXP = Expect, EASY = EasyUnd, INT = Inter

USEVARIABLES ARE RDEXP-SCINT;

 CLUSTER = IDCLASS;

! Classroom ID as the cluster variable

 WEIGHT = HOUWGT;

! House weights to account for sampling bias

 MISSING ARE ALL(-99);

 ! Missing values are specified as -99

ANALYSIS: TYPE = COMPLEX;

ESTIMATOR = MLR;

 H1ITERATIONS = 4000;

MODEL: ! Specify the general factor Gf

 Gf BY

 RDEXP@1

 RDEASY\*

 RDINT\*

 MAEXP\*

MAEASY\*

MAINT\*

SCEXP\*

SCEASY\*

SCINT\*;

 ! Specify the teaching aspect factors

 Expect BY

RDEXP@1

 MAEXP\*

 SCEXP\*;

 EasyUnd BY

RDEASY@1

 MAEASY\*

 SCEASY\*;

 Inter BY

RDINT@1

 MAINT\*

 SCINT\*;

 ! Specify the subject domain factors

 Read BY

RDEXP@1

 RDEASY\*

 RDINT\*;

 Math BY

MAEXP@1

 MAEASY\*

 MAINT\*;

 Science BY

SCEXP@1

 SCEASY\*

 SCINT\*;

 ! Freely estimate factor and residual variances

 Gf-Science\*;

 RDEXP-SCINT\*;

 ! Restrict factor covariances to zero

 Gf-Science WITH Gf-Science@0;

 ! Freely estimate item intercepts

 [RDEXP-SCINT\*];

OUTPUT: stdyx;

1. Multilevel bifactor structural equation model of student assessments (measurement model)

TITLE: ML-BFSEM of student assessments

DATA: FILE IS timss2011.dat;

VARIABLE: NAMES ARE IDCLASS IDSTUD HOUWGT FIN NOR RDEXP RDEASY RDINT MAEXP MAEASY MAINT SCEXP SCEASY SCINT;

 ! Item labelling:

 ! RD = Reading, MAT = Mathematics, SC = Science

 ! EXP = Expect, EASY = EasyUnd, INT = Inter

 USEVARIABLES ARE RDEXP-SCINT;

 CLUSTER = IDCLASS;

! Classroom ID as the cluster variable

 WEIGHT = HOUWGT;

! House weights to account for sampling bias

 MISSING ARE ALL(-99);

 ! Missing values are specified as -99

ANALYSIS: TYPE = TWOLEVEL;

ESTIMATOR = MLR;

 H1ITERATIONS = 4000;

MODEL: %WITHIN%

! Student level (W)

 ! Specify the general factor GfW

 GfW BY

 RDEXP@1

 RDEASY\*

 RDINT\*

 MAEXP\*

MAEASY\*

MAINT\*

SCEXP\*

SCEASY\*

SCINT\*;

 ! Specify the teaching aspect factors (W)

 ExpectW BY

RDEXP@1

 MAEXP\*

 SCEXP\*;

 EasyUndW BY

RDEASY@1

 MAEASY\*

 SCEASY\*;

 InterW BY

RDINT@1

 MAINT\*

 SCINT\*;

 ! Specify the subject domain factors (W)

 ReadW BY

RDEXP@1

 RDEASY\*

 RDINT\*;

 MathW BY

MAEXP@1

 MAEASY\*

 MAINT\*;

 ScienceW BY

SCEXP@1

 SCEASY\*

 SCINT\*;

 ! Freely estimate factor and residual variances

 GfW-ScienceW\*;

 RDEXP-SCINT\*;

 ! Restrict factor covariances to zero

 GfW-ScienceW WITH GfW-ScienceW@0;

%BETWEEN%

! Classroom level (B)

! Specify the general factor GfB

GfB BY

RDEXP@1

 RDEASY@1

 RDINT@1

 MAEXP@1

 MAEASY@1

 MAINT@1

 SCEXP@1

 SCEASY@1

 SCINT@1;

 ! Specify the teaching aspect factors (B)

 ExpectB BY

RDEXP@1

 MAEXP\*

 SCEXP\*;

 EasyUndB BY

RDEASY@1

 MAEASY\*

 SCEASY\*;

 InterB BY

RDINT@1

 MAINT\*

 SCINT\*;

 ! Specify the subject domain factors (B)

 ReadB BY

RDEXP@1

 RDEASY@1

 RDINT@1;

 ScienceB BY

SCEXP@1

 SCEASY@1

 SCINT@1;

! Freely estimate factor and residual variances

 GfB-ScienceB\*;

 RDEXP-SCINT\*;

 ! Restrict factor covariances to zero

 GfB-ScienceB WITH GfB-ScienceB@0;

 ! Freely estimate item intercepts

 [RDEXP-SCINT\*];

OUTPUT: stdyx;

1. Multi-group multilevel bifactor structural equation model of student assessments including the relations to student achievement

TITLE: Multi-group ML-BFSEM of student assessments and freely estimated relations to student achievement

DATA: FILE IS timss2011\_list.dat;

 TYPE = IMPUTATION;

 ! Run the analyses for each of the five plausible

 ! values and combine the results (model parameter)

VARIABLE: NAMES ARE IDCLASS IDSTUD HOUWGT FIN NOR RDEXP RDEASY RDINT MAEXP MAEASY MAINT SCEXP SCEASY SCINT

RDACH MATACH SCACH CNT;

 ! Item labelling:

 ! RD = Reading, MAT = Mathematics, SC = Science

 ! EXP = Expect, EASY = EasyUnd, INT = Inter

 ! ACH = Achievement

 USEVARIABLES ARE RDEXP-SCACH;

 CLUSTER = IDCLASS;

! Classroom ID as the cluster variable

 WEIGHT = HOUWGT;

! House weights to account for sampling bias

 MISSING ARE ALL(-99);

 ! Missing values are specified as -99

 GROUPING IS CNT (1=FIN 2=NOR 3=SWE);

 ! Specification of the grouping variable (country)

ANALYSIS: TYPE = TWOLEVEL;

ESTIMATOR = MLR;

 H1ITERATIONS = 4000;

MODEL: %WITHIN%

! Student level (W)

 ! Specify the general factor GfW

 GfW BY

 RDEXP@1

 RDEASY\*

 RDINT\*

 MAEXP\*

MAEASY\*

MAINT\*

SCEXP\*

SCEASY\*

SCINT\*;

 ! Specify the teaching aspect factors (W)

 ExpectW BY

RDEXP@1

 MAEXP\*

 SCEXP\*;

 EasyUndW BY

RDEASY@1

 MAEASY\*

 SCEASY\*;

 InterW BY

RDINT@1

 MAINT\*

 SCINT\*;

 ! Specify the subject domain factors (W)

 ReadW BY

RDEXP@1

 RDEASY\*

 RDINT\*;

 MathW BY

MAEXP@1

 MAEASY\*

 MAINT\*;

 ScienceW BY

SCEXP@1

 SCEASY\*

 SCINT\*;

 ! Freely estimate factor and residual variances

 GfW-ScienceW\*;

 RDEXP-SCINT\*;

 ! Restrict factor covariances to zero

 GfW-ScienceW WITH GfW-ScienceW@0;

 ! Relations to student achievement

 ! Teacher aspects and general factor as predictors

 RDACH MATACH SCACH ON GfW-InterW;

 ! Subject domain factors as predictors

 RDACH ON ReadW;

 MATACH ON MathW ReadW;

 SCACH ON ScienceW ReadW;

%BETWEEN%

! Classroom level (B)

! Specify the general factor GfB

GfB BY

RDEXP@1

 RDEASY@1

 RDINT@1

 MAEXP@1

 MAEASY@1

 MAINT@1

 SCEXP@1

 SCEASY@1

 SCINT@1;

 ! Specify the teaching aspect factors (B)

 ExpectB BY

RDEXP@1

 MAEXP\*

 SCEXP\*;

 EasyUndB BY

RDEASY@1

 MAEASY\*

 SCEASY\*;

 InterB BY

RDINT@1

 MAINT\*

 SCINT\*;

 ! Specify the subject domain factors (B)

 ReadB BY

RDEXP@1

 RDEASY@1

 RDINT@1;

 ScienceB BY

SCEXP@1

 SCEASY@1

 SCINT@1;

! Constrain factor variances

 GfB-ScienceB\*(v1-v6);

! Freely estimate item residual variances

 RDEXP-SCINT\*;

 ! Restrict one factor mean

 [SayB\*](m1);

 ! Restrict factor covariances to zero

 GfB-ScienceB WITH GfB-ScienceB@0;

 ! Estimate item intercepts

 ! They are constrained to equality across countries

 ! in this model.

 [RDEXP-SCINT\*];

 ! Relations to student achievement

 ! Teacher aspects and general factor as predictors

! Note: InterB was excluded due to non-convergence

! of the model with InterB.

 RDACH MATACH SCACH ON GfB-EasyUndB;

 ! Subject domain factors as predictors

 RDACH ON ReadB;

 MATACH ON ReadB;

 SCACH ON ScienceB ReadB;

OUTPUT: stdyx;