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Sampling Design of Large-Scale Assessments and Implications for Data Analyses

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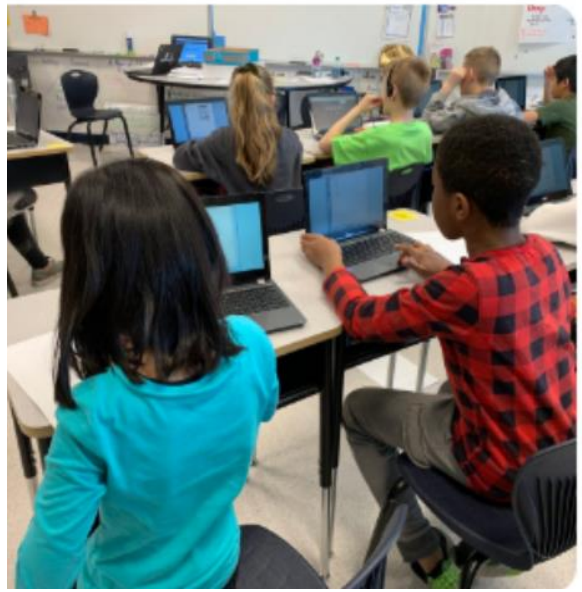
Agenda

- Overview of large-scale assessments (LSA)
- Study designs
  - Complex sample design (multi-stage, clustered sample design, sampling weights, variance estimation and standard errors)
  - Complex assessment design (rotated design, use of Item Response Theory (IRT) and Plausible Values (PVs))



What are educational large-scale assessments (LSA)?

Tests that focus on measuring and monitoring what populations know and can do in academic subject areas

- Populations are usually certain ages/grade in cities, states, countries
- Subpopulation measurement (gender, SES, race/ethnicity) is also prioritized
- Academic subject areas include mathematics, science, reading, social studies, computer literacy, etc.
- Measure contextual factors associated with achievements
- National assessments like NAEP for the United States allow for trend monitoring and comparisons between states and large cities
- International assessments like TIMSS, PIRLS, and PISA allow for country-level trend monitoring and between-country comparisons

Uses of LSAs

Provide information for achievement comparisons between educational systems or jurisdictions

- *How does the performance in one country compare with that of other countries?*

Examine trends in achievement

- *How does one country's achievement increase or decrease over time?*

Improve education by informing policy, research, and practices

- *What factors are associated with educational achievement? What can we learn from others about what works (and what doesn't)? What could be adopted by or adapted?*

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Why Specialized Software Programs are Needed for LSA Data Analysis?

Study Designs

- Complex sample design (multi-stage, clustered sample design, sampling weights, sampling variance)
- Complex assessment design (matrix sampling design, use of Item Response Theory (IRT) and Plausible Values (PVs), and measurement variance)

Sample Design, Sampling Variance and Weights

Why Do We Use Samples?

Impossible to test everyone on everything

- Too many people
- Too many items
- Too expensive

Not necessary to test everyone on everything, e.g.,

- Blood sample
- Soup sample

ELSA context:

- Some students are tested on some items
- Results should be seen in the context of the student and item sample design

Source: Sabine Meinck, Ph.D., IEA, Design of International Large-Scale Assessments and Implications for Multilevel Modeling

You’re probably familiar with simple random sampling (SRS)

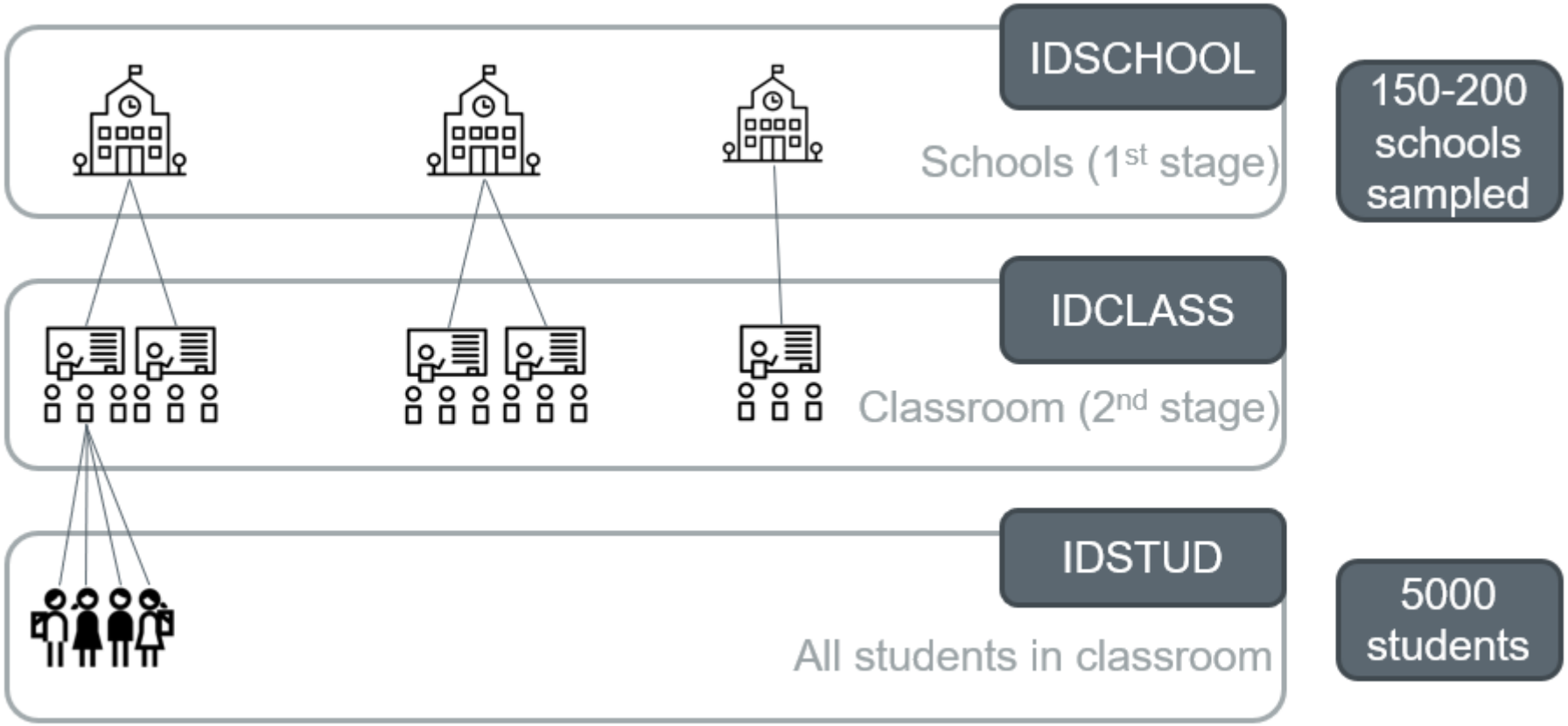
- Each person has an equal probability of selection
- But, to conduct a study with nationally representative samples, SRS not feasible:
- Time!
- Cost!

Complex sample designs

Why “complex”?

- Multiple stages of sampling
- Stratification is used
- Homogenous clusters are sampled
- Selection probabilities differ for different sampling units

Multiple sampling stages (TIMSS)



What are the implications of multistage cluster sampling?

Stage(s) 2/3: Selection of students: Cluster sampling

Cluster effect: Individuals within classrooms/schools tend to be more similar than individuals between schools

What are the implications of multistage cluster sampling? – Cont.

- In general, the sampling variance of a clustered sample tends to be larger than the sampling variance of a simple random sample of the same size.
- In studies using a complex sampling design, standard errors tend to get larger, partly due to the sampling variance.
- Variances are essential in statistical tests of significance
  - Biased variances could make differences between scores appear significant when in fact they are not

How to handle clustering:

Three recommended methods

- Replication methods. TIMSS and NAEP uses jackknife repeated replication
- Taylor series approximations
- Hierarchical linear models

Sampling schools and students: Unequal probabilities of selection

- Schools are sampled with **probability proportional to their size** from the list of all schools in the population
  - Larger schools are more likely to be selected than small ones
  - Students in large schools have a lower probability of selection than classes in smaller schools
  - Result: the overall probability of selection of students is more similar across different size schools

When we sample with unequal probabilities of selection, aren't we introduce bias into our analytical results?

Sample Weights

- To account for unequal probabilities of selection, sampling weights should be used in all statistical calculations where inferences are made to populations
  - Otherwise, population estimates of means or percentages will be biased
  - Most standard software have ways to specify weights

TIMSS Student Weights

Final student weights = school-level sampling probability * student-level sampling probability*non-participation adjustments

- Students are assigned sampling weights to adjust for over- or under-representation of particular groups in the final sample
- **Student weight is the inverse of the probability of selection**
- Students with higher weight values are representing more people in the target population
- Use of sampling weights is necessary for computation of sound, representative estimates
- Weights adjust for nonparticipation
- Sum of the overall student weights equals the number of students in the target population

Probabilities and Weights

- **Student weight is the inverse of the probability of selection**
- Suppose a school has a probability of selection of 0.1 and each student within a school has a probability of selection of 0.2. What is the students' probability of selection?

School prob	Student within school prob	Joint Prob
1/10	2/10	2/100 or 1/50

- Student weight = inverse probability

  50/1 = 50

Q: If a school has a 0.2 probability of selection and once school is selected the student has a 0.05 probability of selection, what is the students weight?

A. 100

B. 200

C. 20

D. 1000

Implications for Large-Scale Data Analysts

- Many statistical software packages assume the data being analyzed come from a simple random sample with independent observations and equal selection probability
- ELSAs clustering of observations in schools and classes prevents them from being independent
  - Need to use the JK, Taylor series or HLM method for sampling variance
- Multistage sampling leads to unequal selection probability
  - Weights need to be applied for unbiased estimates
- Statistical software exists for “complex samples”
  - NCES’s EdSurvey and Dire!

Resources

IEA TIMSS International Database

IEA International Database Analyzer (IDB Analyzer) and its tutorials

NCES International Data Explorer (IDE)

NCES *EdSurvey* R statistical package

NCES *Dire* R statistical package

NCES Distance Learning Dataset Training Modules (DLDT)

NCES International Activities Program website

TIMSS and PIRLS International Study Center website

IEA website

ILSA Gateway

OECD PISA website

Questions?

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