An Adaptive Learning Environment for Statistics
A proposal

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Note

Compared with the paper, the slides include additional material and clarifications

Outline

1 Adaptive learning

2 Introductory example. A flavor of the proposed system

3 Database / knowledge base structure

4 Learner-directed learning

5 Assessment and tracking progress. Student grading

6 Brief thoughts on evaluation of the system

7 Conclusions

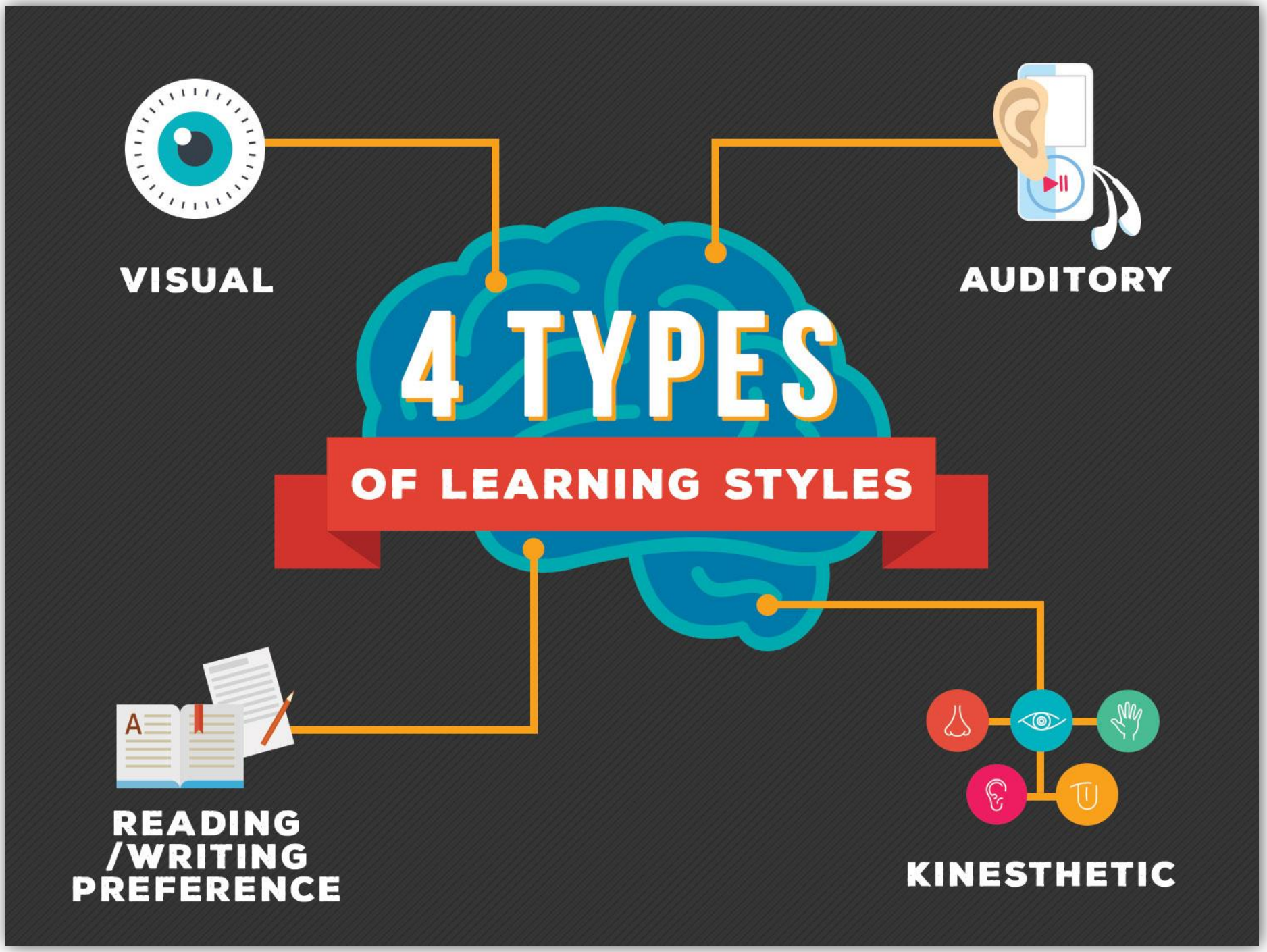
1 Adaptive Learning

1.0 Adaptive Learning Ingredients

1.0.1 Learning goals and objectives

1.0.2 Existing knowledge

1.0.3 Cognitive abilities


VISUAL
AUDITORY
4 TYPES
OF LEARNING STYLES
READING
/WRITING
PREFERENCE
KINESTHETIC

1.1 Adaptive Learning

Provides better ways to learn through
customizable system-supported learning environments.

Individualized learning paths are created considering

- The learner’s learning goals and objectives
- The learner's existing knowledge, cognitive ability, and learning style
  - as known before the learner starts on the learning path
  - as inferred by the system as the learner proceeds through the learning path – continuous adaptation
- The learners progress so far

An extensive knowledge base supports complex reasoning to arrive at recommendations for the learner

Knowledge base populated from

- Expert knowledge (curricula, textbooks, etc.),
- Machine Learning (ML) / Learning Analytics

1.2 Adaptive learning support system

Inputs:	**Learner profile** (knowledge, ability, learning style, etc.). **Learning goal**s and objetives **Extensive knowledge base**
Output:	**Personalized learning path**, a sequence of learning materials. tasks, and activities that lead **from existing knowledge** **to the learning goal.** Presented adaptively, depending on the learner pofile and how the learner progresses through each step.
Extension:	Use as expert knowledge base, e.g. **Statistics Adviser** User can immediately learn what is necessary to carry out the advice. Support for **life-long learning**

2 Introductory example
A flavor of the proposed system

2.1 Persons, esp. in the role of Learners

Person 107	**Application:** Agriculture	**Subject:** Math poor
Completed Units …		
Objective: Obj. 347 Apply t-test	**Outcome:** B	
Xiao Wang		

Person 316	**Application:** Medicine	**Subject:** Math good
Completed Units …		
Objective: Obj. 347 Apply t-test	**Outcome:**A	
Objective: Obj. 348 Explain t-test	**Outcome:**A	
Hans Kohl		

2.2 Learning goals and objectives

Obj 347	Statistics-topic: t-test	easy
Able to apply the t-test. Know when to use.		

Obj 348	Statistics-topic: t-test	hard
Able to explain mathematics of the t-test		

2.3 Presentation Chunk: Definition

PC 436	Stat-topic: **t-test**	Function: **Definition**	Format: **Written text**	Difficulty: **Medium**
Prerequisites: Basic **u**nderstanding of inferential statistics, hypothesis testing, statistical significance				
Objective: Know what a t-test does.				
A t-test is a comparison of two mean values of a given variable, such as math test score, blood pressure, crop yield. It determines if there is a significant difference between the two mean values. We can • compare the mean of one group with a given value, We can determine whether the mean systolic blood pressure in a group is below 150 mmHg • compare pre-test results and post-test results in the same group • compare the means of two independent groups,				

2.4.1 Presentation Chunk: Example

PC 578	Stat-topic: **t-test**	Function: **Example**	Applicattiom: **Agricultur**e	Format: **Written text**
Objective: Experiential understanding of what the t-test does				

Effect of fertilizer mix on wheat yield **under medium-dry conditions**

- Each sample consists of 10 plots which are the same in every respect except
  - plots in sample 1 get fertilizer mix 1
  - plots in sample 2 get fertilizer mix 2
- At the end of the season, wheat yield is measured for each plot and the mean is computed for each sample.
- We want to know whether
  - any difference in the means could be due to chance without any effect of the fertilizer mix used or
  - the difference between means is so large that its occurrence without an effect of the fertilzer mix used would be highly unlikely.

2.4.2 Presentation Chunk: Example

PC 579	Stat-topic: **t-test**	Function: **Example**	Appliication: **Medicine**	Format: **Written text**

Objective: Experiential understanding of what the t-test does

Effect of Amlodipine on lowering blood pressure

- For a group of people with specified characteristics we want to test the effectiveness of Amlodipine vs a placebo in lowering blood pressure.
- We gather a pool of people meeting the criteria by asking for volunteers.
- We draw two random samples from the pool.
  - The people in sample 1 are given Amlodipine (the experimental sample),
  - The people in sample 2 are given a placebo (the control sample).
- For each participant we measure the decrease in blood pressure from the beginning to the end of the trial and compute the mean for each sample.
- We want to know whether
  - any difference in the means could be due to chance without any effect of Amlodipine or
  - the difference between means is so large that its occurrence without an effect of amlodipine would be highly unlikely.

2.5 Learning units

LU 681	Statistics-topic: t-test
Objective: Obj 347 Apply t-test, know conditions	
Parameter A. Math level (from low to high).	
Parameter B. Application domain	
Prerequisites: PC 436 AND (PC 578 OR PC 579), …	
A Learning Unit is a structured set of Presentation Chunks. This LU is customizable by the two parameters, e.g. for a learner with low math level and application domain Agriculture the LU will use example PC 578	

LU 682	Statistics-topic: t-test
Objective: Obj 348 Explain the mathematics of the t-tests	
Parameter A. Math level (>= medium).	
Parameter B. Application domain	
Prerequisites: PC 436 AND (PC 578 OR PC 579), …	

2.6 Presentation Chunk: Exam question

PC 735	**Stat-topic**: t-test	**Function**: Exam question	**Application:** Medicine	**Format:** Written text
Here are the results of a clinical trial of prescribing Bactrim vs. Penicillin for Staphylococcus UTI. Success measured by number of days to relief symptoms. Find out whether there is a significant difference.				

3 Database / Knowledge Base Structure

3.0 Requirements

Requires a very rich database / knowledge base

By necessity complex

3.1 Entity types - a few examples

Next slide

Entity type	Explanation or examples
Person	Can play many roles: **learner**, instructor, author, **...**
PersonCharacteristic	VisualThinker, WritingAbility, EyeSight, Hearing, **...**
LearningObjective	
KnowledgeItem	
. ConceptBroad	Abstract concept, method, named entity
. KnowledgeChunk	Statements of fact, conjecture, prescription, etc.
LearningUnit	A structured set of PresChunks.Can be external
PresentationChunk	A unit that can be presented to a learner …
PresChunkFormat	WrittenText, AudioText, Image, Visualization, Simulation , **...**
PresChunkFunction	Exposition, Example, TestQuestion, Answer, **...**
EntertainmentValue	To select PresentationChunks for reluctant learners

3.2 Some person characteristics
Focus on learner role

- Knowledge of statistics and other mathematics (e.g., calculus)
- Interest in / knowledge of a subject domain (e.g., Education)
- Other interests
- Abilities (cognitive, artistic, sensory, manipulative)
- Learning style
- Attention span
- Tolerance for frustration
- Emotions, attitudes, self-esteem. motivation for learning
- Detailed data om interactions with PresentationChunks and learning outcomes
  (for convenience, these data are stores both with the PresentationChunk and the Person)

3.3 Learning goal / objective information

- Standards and other source in which the learning objective is included
- Short name, synonyms
- Definition, explanation
- Position in the hierarchy of learning goals and objectives
- How to assess. Measures, if any
- Much information about
  - connected learning units and presentation chunks
  - connected persons and their status of achieving the objective

3.4 Presentation chunk information

- Topic covered
- Application domain (e.g. Agriculture, Medicine, Education)
- Function in the learning process (Introduction, Prerequistes, Definition, Example, Rationale of a statistical test, Conditions for using a statistical test, "Cookbook" prescription of how to carry out a statistical test. testExercise, Assignment, TestQuestion, etc.)
- Format (Media type)
- DifficultyLevel
- EntertainmentValue (high for a cartoon illustrating a statistical concept)
- Learner characteristics for which suitable
- Links to other PresentationChunks. Links can be embedded in the text. The type of link is indicated, such as *elaboration* or *moreFormalExposition* or *definition* (for a term in the text).

3.4 Presentation chunk information 2

- Detailed data on interactions of learners with the PresentationChunk and learning outcomes
  These data include
  - time spent on the chunk (or even more granular,small snippets),
  - performance in small tests,
  - performance in small tests and end-of-a larger-unit test,
  - learner frustration (if system is able to detect),
  - questions the learner asked,
  - explicit feedback from the learner

4 Learner-directed learning

4.1 Many ways of interaction

- This paper focuses on the system function of recommending learning paths, but **supporting learner-directed inquiry**, giving learners the opportunity and the information to chart their own paths or take detours from the system-recommended path **is equally important**. Some ways to do this:
- **Birds-eye navigation: Provide overviews of the conceptual space** indicating the recommended learning path. Can take many forms:
  - concept maps, strand maps, concept hierarchies
  - the equivalent of a book table of contents and chapter outlines,

  f**or the learner to browse** and navigate with the option to drill down to PresentationChunks at any time.
- **On-the-ground navigation through links between navigation chunks** See next slide**.**

4.1 Many ways of interaction

- **Birds-eye navigation: Provide overviews of the conceptual space**
- **On-the-ground navigation through links between navigation chunks** Provide **links to**
  - easier or more difficult or just different versions or different frormats
  - more examples
  - chunks that provide prerequisite knowledge, background. or context that help understand the present chunk, emphasized proactively if the learner navigates to a chunk for which she is not prepared
  - a general help button
  - material that leads further, beyond the standard material in a course (link inserted dynamically based on the learning unit / course the learner is pursuing)
- **Always have a button that brings the learner back to the place in the system- recommended path** from which he or she started an excursion

4.2 Give learners meta-information

- Learners should always know their place in a learning path (see birds-eye navigation above) and what their options are.
- Learners should know the nature of the units the system selects for them. For example, the system should show the degree of difficulty of chunks or units presented to the learner. A learner being presented with mostly easy materials and also being informed that she is working at a B level may decide that she wants to work towards a grade of A and ask to work on commensurately more difficult material.
- The system should explain why a chunk or unit is presented at this point in the learner's customized learning path.

5 Assessment and tracking progress.

Student grading

5.1 Student grading

Assessment of students is based on the achievement of learning objectives.

As a secondary measure, one can also consider the time a student spends on achieving an objective

Some students pay great attention to grades, so the system must

- specify the criteria for grading of a learning unit, especially learning units that correspond to a traditional course (such as a three-semester-credit course in the US)
- let students track their progress

5.1.1 Specifying grade requirements and grade computation

- For each learning unit, there is a list of learning objectives.
- With each learning objective is associated the maximum number of points it can contribute to the total number of points for the unit.
  For recording student achievement, fractional points are allowed.
  Student achievement of a learning objective is shown as a letter grade and as a number of points.
- Maximum points for a unit 100, **grade determined by this scale**
  A = 85 - 100, B = 70 - 84, C = 60 - 69, D = 50 - 59, F= 0 - 49). .
- **In addition, some objectives are required for a given course grade**
  For example,
  - for an A in the course, a student must achieve Course Objective 5 with a minimum grade of B,
  - to pass the course with a grade of B or below, the student need not show any achievement in Course Objective 5.

5.1.1 Objectives required for each course grade

	Course grade of X requires min of total points **and** achieving the objective indicated in the column for each grade with minimum grade given.				Grade/points achieved so far	
	D	C	B	A	Grade	Points
Obj 1	D	D	C	B		
Obj 2				B		
Obj 3	D	D	C	B		
Obj 4	D	D	C	B		
Obj 5				B		
Obj 6	D	D	C	B		
Obj 7			C	B		

5.2 Student monitoring their grades

Students can always check their progress.

They can also ask the system what they need to do to achieve a given grade in the course.

Depending on rules specified by the university, students could re-test for a learning objective n times.

6 Brief thoughts on evaluation of the system

6.1 Evaluation: process measures

- number of clarifying questions from learners,
- number of backtracks,
- Time to complete learning path,
- Number of questions that take the concepts learned further

6.2 Evaluation: Learning outcomes

- Understanding of statistical concepts,
- Knowing when to apply what test,
- Performance on statistics problems, attitude towards statistics,
- Students' confidence in their own ability.
- Later use of statistics in research

Determining learning outcomes for an individual learner is assesement.

To **evaluate the system or system components**, perform analyses over the individual data, such as computing means or analyze learner performance deependent of learner characteristics.

7 Conclusions

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Computer systems, when designed intelligently, can truly individualize learning and revolutionize how students and practitioners learn.

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Questions?

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