Slide 1

Disconnected: High School & Post-secondary grades

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Slide 2

100 Years of Chem Ed Research...

"The achievement of high school and freshman college students in chemistry"

S. R. Powers, *School Sci. Math.*, **1921**, *21(4)*, 366-377

- Data collected starting in **1913**

- Journal of Chemical Education launches in **1924**

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Slide 3

100 Years of Chem Ed Research...

260   JOURNAL OF CHEMICAL EDUCATION   APRIL, 1925

QUESTIONS RELATIVE TO THE CORRELATION OF COLLEGE AND HIGH-SCHOOL CHEMISTRY COURSES

HARRY SHIPLEY FRY, DEPARTMENT OF CHEMISTRY, UNIVERSITY OF CINCINNATI,

"Any attempt to correlate college and high school courses naturally calls for some form of differentiation … between students who **have had [and] have not had** secondary school chemistry"

Harry Fry, *J. Chem. Ed.* **1925**, *2(4)*, 260-269

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Slide 4

100 Years of Chem Ed Research...

"The achievement of high school and freshman college students in chemistry"

Jacob Cornog and George D. Stoddard

J. Chem. Ed., **1925**, *2(8)*, 701-708

- University of Iowa Placement Test

"Predicting failures in general chemistry"
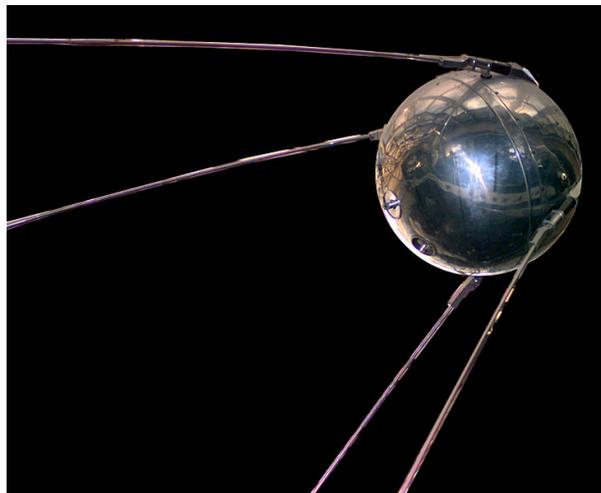
Nelson W. Hovey and Albertine Krohn

J. Chem. Ed., **1958**, *35(10)*, 507-509

- University of Toledo Chemistry Placement Exam

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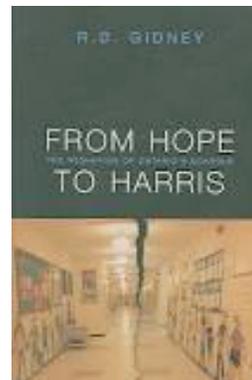
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A series of significant events:

4th October 1957

Recommended reading:

- Robert D. Gidney
  - "From Hope To Harris"
    - U of T Press

A change of course (?):

- Emphasis on concepts:
  - Chemical Bond Approach (CBA)
  - Chemistry Educational Materials Study (CHEM Study – in Ontario from 1967)
  - Nuffield Science (UK)
    - *etc.*

Ontario S-17, 1952 (grade 11-12):

CHEMISTRY

Changes of state
(7 periods)

The three states of matter and their general characteristics. Melting and freezing, illustrated by water and naphthalene. Melting points as characteristic physical constants. Evaporation and condensation, illustrated by water or carbon tetrachloride.
…
Sublimation, illustrated by iodine, benzoic acid, or naphthalene...

Mechanical mixtures. (6 periods)

Study of such mechanical mixtures as iron and sulphur; copper filings and charcoal; clay and water; kerosene and water; sugar and sand. This should include a discussion of (i) properties of mixtures in relation to properties of the constituents, (ii) methods of separation.
Study of naturally occurring mixtures.. e.g. lake-shore sand, milk, tomato juice.
Methods of separation of mixtures industrially; e.g. settling, filtering, centrifuging, froth flotation, magnetic separation, distillation.

Ontario S-17D, 1966 (grade 12)

Unit I: Introduction (1½ weeks)

1. Scope of chemistry and its relationships with other sciences and mathematics
   Nature of the scientific method
2. The chemist's view of matter as made up of a finite number of pure substances, sometimes occurring isolated, but more often occurring in mixtures
3. Properties as characteristics which identify pure substances, e.g., colour, density, boiling point, melting point, conduction of electricity, etc.
4. Classification of pure substances as elements (characteristics, including reference to limit of decomposition) or compounds (characteristics, including constant composition)
5. Physical change and chemical change
   Synthesis and decomposition

Experiments

(a) Boiling point of water, or carbon tetrachloride, or methanol
(b) Melting point of naphthalene, or paradichlorobenzene
(c) Quantitative decomposition of various samples of mercury (II) oxide
(d) Synthesis of a sulphide (copper and zinc)

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Ontario S-17E, 1968 (grade 13)

• based on "Chemistry – An Experimental Science" (1963)
  – US CHEM Study course text (Canadian SI edition)

UNIT 1:	Introduction	3
UNIT 2:	Energy Effects in Chemical Reactions	4
UNIT 3:	The Rates of Chemical Reactions	4
UNIT 4:	Equilibrium in Chemical Reactions	5
UNIT 5:	Solubility Equilibria	5
UNIT 6:	Aqueous Acids and Bases	6
UNIT 7:	Oxidation-Reduction Reactions	6
UNIT 8:	Experimental Basis for the Atomic Theory	7
UNIT 9:	Electron Arrangement and the Periodic Table	7
UNIT 10:	Molecules in the Gas Phase	8
UNIT 11:	The Bonding in Solids and Liquids	8
UNIT 12:	The Chemistry of Carbon Compounds	9

1. Heat and Chemical Reactions
   a) The water-gas reaction
   b) The heat content of a substance
   c) Additivity of reaction heats
   d) The measurement of reaction heat: calorimetry
   e) Calculation of heat of reaction, $\triangle H$

2. The Law of Conservation of Energy
   a) Conservation of kinetic and potential energy
   b) Conservation of energy in a chemical reaction

3. The Energy Stored in a Molecule
   a) The energy of a molecule: molar heat content
   b) Energy changes on warming

4. The Energy Stored in a Nucleus

Experiment: The heat of reaction

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A fork in the road...

• Quantitative analysis
  – grades (chemistry, maths, physics)
  – SAT/ACT scores
  – IQ test scores

• Qualitative analysis
  – "other"

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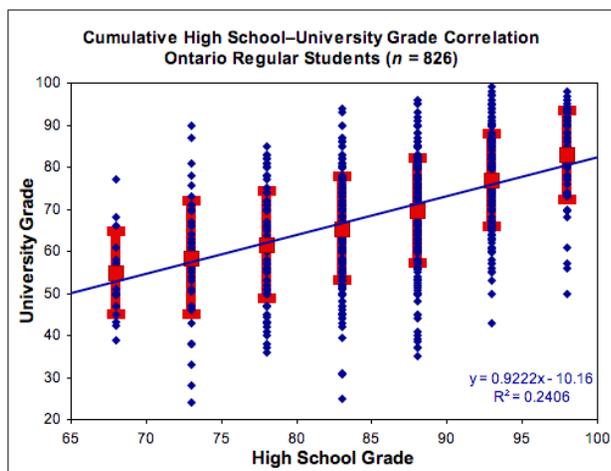
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Fast forward...

• Quantitative studies to 1967:

"There is some indication that the taking of high school chemistry **may** be used as an indicator of success ... There are indications that [other parameters] **may** be better, or at least as good, as indicators. **There is also evidence that no indicator is all that good.**"

William R. Ogden, *School Sci. Math.*, **1976**, *76*, 122-126

(emphasis added)

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The first-year experience:

Cumulative High School–University Grade Correlation
Ontario Regular Students (n = 826)

$y = 0.9222x - 10.16$
$R^2 = 0.2406$

- 1st year chemistry
- 2006-2010 surveys
- WD & DNW omitted
- HS mean = 86 ± 7
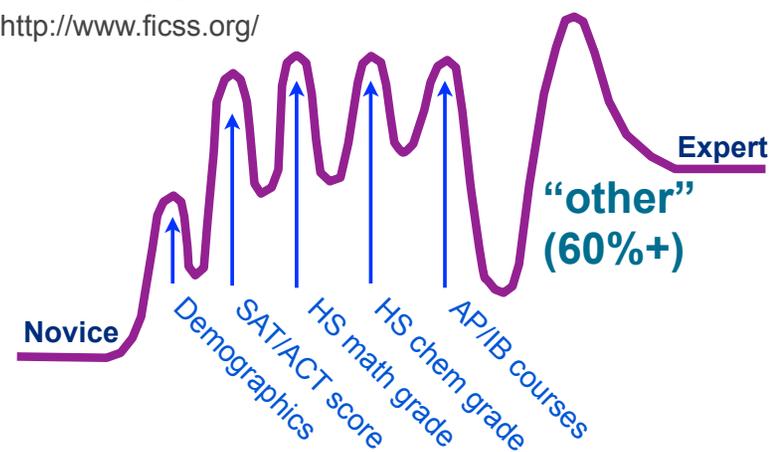- Uni mean = 69 ± 14
- Mean Uni *vs.* HS R^2 = 0.9752

http://www.chem.utoronto.ca/~dstone/Research/survey.html

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Factors in college science success: FICSS

http://www.ficss.org/

Expert

"other" (60%+)

Novice

Demographics
SAT/ACT score
HS math grade
HS chem grade
AP/IB courses

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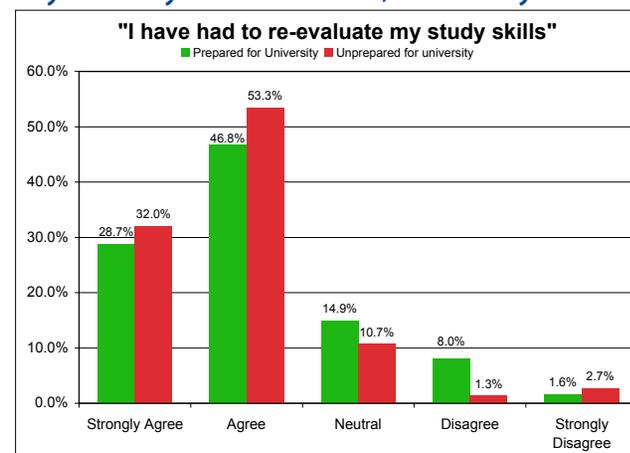
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Explaining the "other":

- Misconceptions (alternative conceptions)
- Threshold concepts (?)
- Intellectual development (Perry/Piaget/*etc.*)
- Learning "style":
  - approach, aptitude, & temperament
- Perceived learning environment:
  - workload, teaching style, assessment practices

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Student study skills:

- Survey of 1st-year students, end-of-year:

"I have had to re-evaluate my study skills"

- Prepared for University
- Unprepared for university

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Prepared	28.7%	46.8%	14.9%	8.0%	1.6%
Unprepared	32.0%	53.3%	10.7%	1.3%	2.7%

http://www.chem.utoronto.ca/~dstone/Research/survey.html

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Ways of learning:

Student motivation & intention | Instructional practices | Outcome (quality)

Achieving — Meaning — Reproducing
Goal-driven — Intrinsic — Extrinsic
Strategic — Deep — Surface

Orientation → Motivation → Style

Approach to content
Teaching / Content
Strategy / Process
& learning tasks
Assessment / Workload

→ Understanding

Deep

Surface

http://www.chem.utoronto.ca/~dstone/Research/bibliography.html
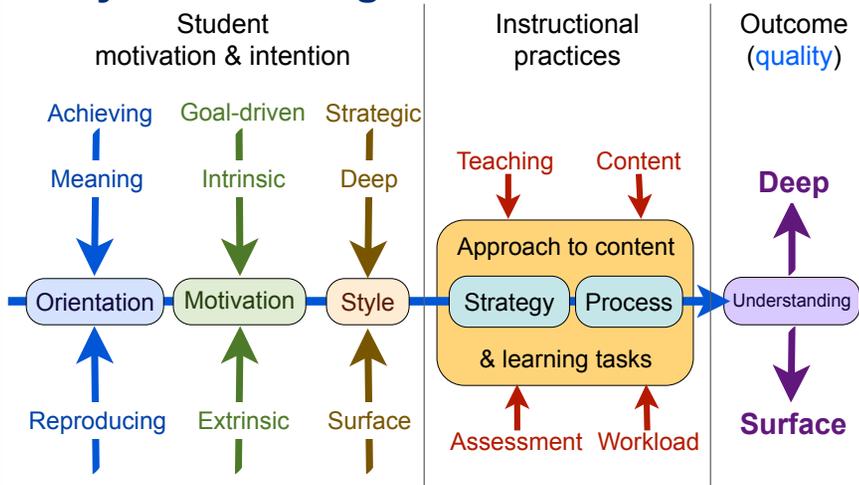
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ASSIST Inventory (Entwistle *et al*):

Deep, Strategic — Surface, Apathetic

Deep — Strategic — Surface

Relating ideas — Using evidence
Time management — Organized studying
Fear of failure — Rote memory

Interest in ideas / Monitoring understanding
Alertness to assessment & monitoring studying
Syllabus-bound focus on minimum requirements

Intention to seek meaning for yourself
Intention to achieve the highest grades
Intention to cope minimally with requirements

http://www.etl.tla.ed.ac.uk/questionnaires/ASSIST.pdf

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ASSIST Main scale correlations

- Pearson's *r* values:
  - 1st-year chemistry students (life sciences), *n* = 394

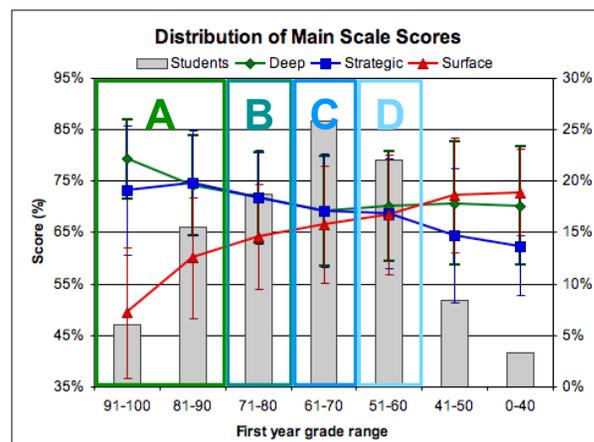| Scale:	Deep	Strategic	Surface
1st-year	0.1960	0.2859	**−0.4060**
Deep		**0.4561**	**−0.3545**
Strategic			−0.2528

All *r* values statistically significant @ 99.99% CL ($p < 10^{-4}$)

$$t = \frac{|r|\sqrt{n-2}}{\sqrt{1-r^2}};\ H_0(r=0)$$

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ASSIST Scores and grades

Mean normalised scores by grade range for 1st-year chemistry students (life sciences) *n* = 394; error bars are ±1 s.d.

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ASSIST Deep scale correlations

• Correlation with 1st-year grade:

| Sub-scale	r	Comment
Deep	0.1960	weak*
Seeking meaning	0.1962	weak**
Interest in ideas	0.1850	weak**
Use of evidence	0.1719	weak**
Relating ideas	0.0622	none

* r values statistically significant @ 99.99% CL ($p < 10^{-4}$)
** r values statistically significant @ 99.9% CL ($p < 10^{-3}$)

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ASSIST Deep scale:

Possible scores 5 – 20

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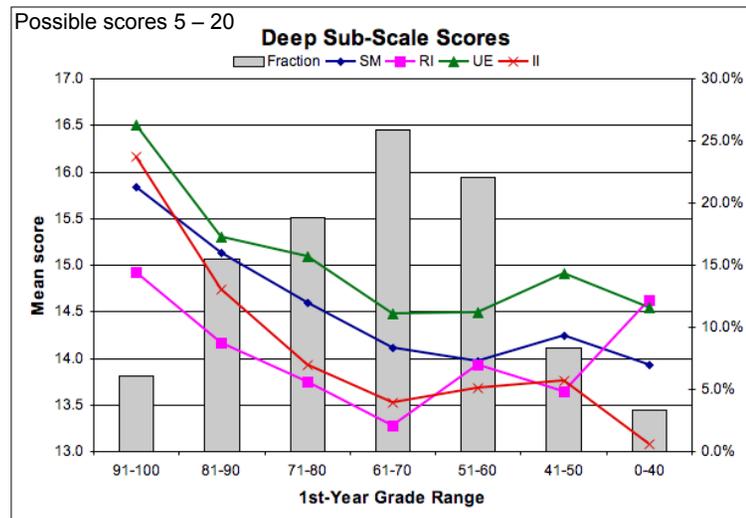
ASSIST Deep scale

• Specific questions impacting grades:
  – Positive correlation with grade:
    • When I'm reading an article or book, I try to find out for myself exactly what the author means (SM)
    • It's important for me to be able to follow the argument, or to see the reason behind things (UE)
  – Negative correlation with grade
    • When I'm working on a new topic, I try to see in my own mind how all the ideas fit together (RI)

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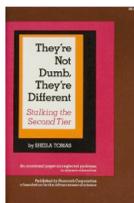
ASSIST Strategic correlations

• Correlation with 1st-year grade:

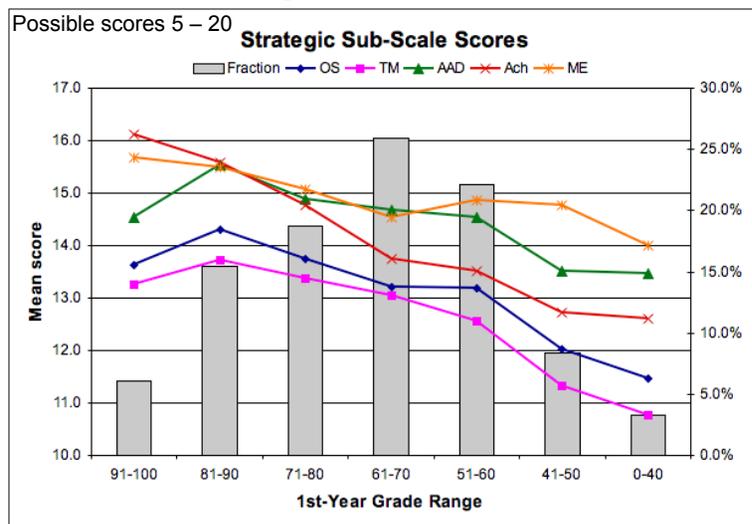| Sub-scale	r	Comment
Strategic	0.2859	medium*
Achieving orientation	0.3782	strong*
Organised studying	0.2148	medium*
Time management	0.1942	weak**
Alert to assessment	0.1645	*weak*
Monitoring effectiveness	0.1506	*weak*

* r values statistically significant @ 99.99% CL ($p < 10^{-4}$)
** r values statistically significant @ 99.9% CL ($p < 10^{-3}$)

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ASSIST Strategic scale

Possible scores 5 – 20

Strategic Sub-Scale Scores

Legend: Fraction, OS, TM, AAD, Ach, ME

Mean score (y-axis left, 10.0 to 17.0; y-axis right, 0.0% to 30.0%)

1st-Year Grade Range (x-axis): 91-100, 81-90, 71-80, 61-70, 51-60, 41-50, 0-40

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ASSIST Strategic scale

- Specific questions impacting grades
  - Positive correlation with grade:
    - I feel that I'm getting on well, and this helps me put more effort into the work (Ach)
    - I go over the work I've done carefully to check the reasoning and that it makes sense (ME)
    - I work steadily through the semester, rather than leaving it all until the last minute (TM)
    - I keep an eye open for what lecturers seem to think is important and concentrate on that (AA)
    - I'm pretty good at getting down to work whenever I need to (TM)

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Keeping up with the pace:

- CHM139 Intro Phys Chem Unit 4 (6 x 50 mins)
  - Arrhenius acids & bases
    - strong and weak
    - autoionization of water
    - pH scale and calculations
    - exceptions, leading to…
  - Brønsted-Lowry acids & bases
    - conjugate acid-base pairs
    - K_a and K_b calcs (incl. polyprotic)
    - structure, bonding, & acid strength
    - neutralization & salts
    - mixed salts, amphiprotic cmpds.
  - Lewis acids & bases
    - structure, reactions
  - Buffers
    - operation & uses
    - pH & buffer capacity
  - Titrations
    - strong & weak acids + base
    - weak base–strong acid
    - indicators & pH curves
  - Solubility & Complexation
    - K_{sp} calculations
    - K_f calculations
    - pH manipulation
    - examples & applications

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Time management

- "I work best under pressure"

http://http-server.carleton.ca/~tpychyl/carpe_diem/cartoons.html

http://www.procrastination.ca/

http://www.procrastinatorsdigest.com/

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ASSIST Surface scale correlations

• Correlation with 1st-year grade:

| Sub-scale	r	Comment
Surface	−0.4060	strong*
Unrelated memorising	−0.3722	strong*
Fear of failure	−0.3322	strong*
Lack of purpose	−0.3028	strong*
Syllabus bound-ness	−0.2177	medium*

* r values statistically significant @ 99.99% CL ($p < 10^{-4}$)

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ASSIST Surface scale

Possible scores 5 – 20

Surface Sub-Scale Scores

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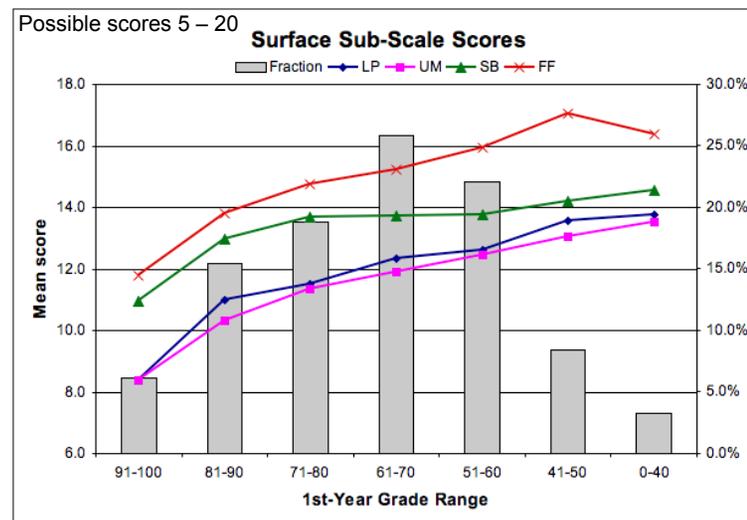
ASSIST Surface scale

• Specific questions impacting grades

– Negative correlation with grade

• I'm not really interested in this course, but I have to take it for other reasons (LP)

• I'm not really sure what's important in lectures so I try to get down all I can (UM)

• I often have trouble making sense of the things I have to remember (UM)

• There's not much of the work here that I find interesting or relevant (LP)

• Often I feel I'm drowning in the sheer amount of material we're having to cope with (FF)

• Much of what I'm studying makes little sense: it's like unrelated bits and pieces (UM)

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Study skills catch 22:

• High school

"Not explicitly teaching study skills since there is only time for curriculum content"

• University

"Not explicitly teaching study skills since students must have them as they gained admission"

Tait & Entwistle, *Higher Education*, **1996**, *31*, 97-116

Student Academic Success Centres
Student Academic Writing Centres
Facilitated Peer Study Groups
http://www.samford.edu/how-to-study/

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Research teams:

- 2006-7:
  - Robin Baj, Michael Lebenbaum, Sujan Saundarakumaran, Derrick Tam, & Jakub Vodsedalek
- 2007-8:
  - Mena Gewarges, Cindy Hu, Gordon Ng, Jana Pfefferle, and Curtis Wang
- 2008-9:
  - Marlena Colasanto, Lauren Cosolo, Darrin Gao, Inna Genkin, Kelly Hoang, Justina Lee, Bryan Nguyen, and Emily Plobner
- 2010-11:
  - Shirin Dason, Xi Nuo Gao, James Hong, Jing Lu, He Zhen Ren, and Heba Shamsi

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- Noel Entwistle (ASSIST) for assistance (!)

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http://www.chem.utoronto.ca/~dstone/Research/survey.html

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