Supplementary Material

The following supplementary materials include samples of measures used within and across studies reported in the manuscript as well as select analyses to support statements made regarding research outcomes.

1 Measures

1.1 Representative Learning Task Inventory

Which of the following learning tasks can you do well right now?

1. *recognize* by name the common functional groups in organic chemistry
2. *recognize* by structure the common functional groups in organic chemistry
3. *define* isomers
4. *define* constitutional isomers
5. given the molecular formula for any organic compound, *determine* its number of degrees of unsaturation (a.k.a. double bond equivalents)
6. given the molecular formula for any organic compound, *draw* structures for all constitutional isomers
7. *memorize* the names of the C1-C10 straight-chain alkanes and alkyl groups
8. use IUPAC rules to *name* branched alkanes
9. *draw* the structure of any alkane given its IUPAC name
10. *name* cycloalkanes and substituted cycloalkanes using IUPAC rules
11. *draw* the structure of a cycloalkane or substituted cycloalkane given its IUPAC name
12. *describe* the relationship between the heat of combustion for a given cycloalkane and its stability
13. given the structure of an organic compound, *identify* primary (1°), secondary (2°), tertiary (3°), and quaternary (4°) carbons
14. given the structure of an organic compound, *identify* primary (1°), secondary (2°), and tertiary (3°) alkyl halides
15. given the structure of an organic compound, *identify* primary (1°), secondary (2°), and tertiary (3°) alcohols
16. given the structure of an organic compound, *identify* primary (1°), secondary (2°), and tertiary (3°) amines
17. *explain* what is meant by the *conformation* of an organic compound
18. *explain* why organic compounds possessing C-C single bonds may exist in more than one conformation
19. for any given acyclic (a.k.a. open chain) organic compound, *draw* all eclipsed and staggered conformations about a particular C-C single bond in Newman projection format
20. given a series of conformations in Newman projection format, *rank* them in terms of their relative stability
21. *define* torsional strain
22. *define* steric strain
23. *identify* gauche relationships within a given organic molecule given its Newman projection formula

24. *identify* anti relationships within a given organic molecule given its Newman projection formula
25. *draw* the lowest energy (i.e., most stable) conformation of each of the C3-C6 cycloalkanes
26. *explain* the relative stabilities of the C3-C6 cycloalkanes in terms of the angle strain and torsional strain that each experiences
27. *recognize* Newman projection formulas for the C3-C6 cycloalkanes, and substituted derivatives thereof, when viewed down a particular C-C single bond
28. *draw* cyclohexane in its chair conformation, complete with equatorial and axial hydrogens
29. given the IUPAC name of a substituted cyclohexane, *draw* both chair conformations
30. given a "hexagonal" representation (i.e., possessing a flat cyclohexane ring) of a substituted cyclohexane, *draw* both chair conformations
31. *define* stereoisomers
32. *explain* why *cis-trans* stereoisomers of substituted cycloalkanes exist
33. given an IUPAC name, accurately *represent* the structures of *cis-trans* isomers of substituted cycloalkanes, particularly substituted cyclohexanes
34. given the two chair conformations of a substituted cyclohexane, *determine* which one is more stable (i.e., lower in energy)
35. given the structure of a substituted cycloalkane, *state* the relationship (*cis-trans*) between various substituents
36. *apply* the provided flow chart to answer the question, "What is the relationship between the following compounds?" as it pertains to identical compounds, conformations of the same compound (conformers), constitutional isomers and *cis-trans* stereoisomers

1.2 Fidelity Measure

How many of the LTI items did you read through?

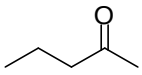
None	Some	About Half	Most	All
1	2	3	4	5

1.3 LTI Quiz with Full Feedback

1. Learning Task: *recognize* by structure the common functional groups in organic chemistry

   Question:

   Which functional group does the compound below possess?



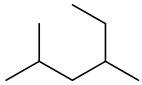
   (a) alcohol (b) ether (c) aldehyde (d) ketone

   Feedback: The correct answer is (d). An alcohol possesses a carbon connected to a hydroxyl (OH) group by a single bond. An ether possesses an oxygen connected to two carbons by single bonds. An aldehyde possesses a carbon connected to another carbon and a hydrogen by single bonds, and an oxygen by a double bond. A ketone possesses a carbon connected to two other carbons by single bonds, and an oxygen by a double bond.

2. Learning Task: use IUPAC rules to *name* branched alkanes

   Question:

   What is the IUPAC name of the following branched alkane?



   (a) 2-ethyl-4-methylpentane

   (b) 2-methyl-4-ethylpentane

   (c) 2,4-dimethylhexane

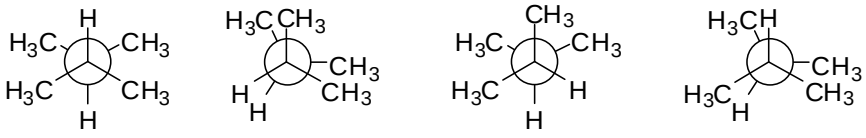
   (d) 3,5-dimethylhexane

   Feedback: The correct answer is (c). Step 1: Identify the longest continuous chain (6 carbons = hexane); Step 2: Identify substituents (2 x methyl); Step 3: Use the prefix 'di' to indicate two identical substituents (dimethyl); Step 4: Indicate the position of each substituent along the longest continuous chain, numbering from the end closer to a substituent (2,4-dimethyl); Step 5: Place substituents before name of longest continuous chain (2,4-dimethylhexane).

3. Learning Task: given a series of conformations in Newman projection format, *rank* them in terms of their relative stabilities

   Question:

   Which of the following represents the most stable conformation of 2,3-dimethylbutane?



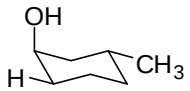
(a) (b) (c) (d)

   Feedback: The correct answer is (a). *Staggered* conformations are always more stable than *eclipsed* conformations. (b) and (d) are eclipsed conformations. (a) is more stable than (c) because it has less *steric* strain owing to fewer *gauche* interactions of methyl groups. (a) has *two* destabilizing gauche interactions; (c) has *three* destabilizing gauche interactions.

4. Learning Task: given the structure of a substituted cycloalkane, *state* the relationship (*cis-trans*) between various substituents

   Question:

In the structure below, what is the relationship (*cis*- vs *trans*-) between the indicated hydrogen and the –OH and –CH_3 group?



(a) The indicated H is *cis* to the -OH and *cis* to the -CH_3.

(b) The indicated H is *cis* to the -OH and *trans* to the -CH_3.

(c) The indicated H is *trans* to the -OH and *cis* to the -CH_3.

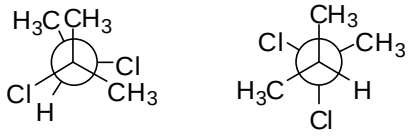
(d) The indicated H is *trans* to the -OH and *trans* to the -CH_3.

Feedback: The correct answer is (b). The H indicated is "up" relative to the other H (not shown) attached to the same carbon. The –OH is "up" relative to the H (not shown) attached to the same carbon. The –CH_3 is "down" relative to the H (not shown) attached to the same carbon. Because the indicated H and the –OH are both "up", they are *cis* to one another. Because the indicated H is up and the –CH_3 is down, they are *trans* to one another.

5. Learning Task: *apply* the provided flow chart to answer the question, "What is the relationship between the following compounds?" as it pertains to identical compounds, conformations of the same compound (conformers), constitutional isomers and *cis*-*trans* stereoisomers

Question:

What is the relationship between the following compounds?



(a) identical compounds

(b) conformations of the same compound

(c) constitutional isomers

(d) *cis*-*trans* stereoisomers

Feedback: The correct answer is (c). The structures have the same molecular formula but a different atomic connectivity. Therefore, they are constitutional isomers.

6. Indicate your expected score (out of 5) for this quiz. (question asked before feedback received)

(a) 1 (b) 2 (c) 3 (d) 4 (e) 5

1.4 Post-Quiz Survey

1. Overall, rate the level of difficulty of the quiz?
    1. much more difficult than expected
    2. more difficult than expected
    3. as expected
    4. less difficult than expected
    5. much easier than expected
2. In comparison to the LTIs you had to study from, how would you rate the difficulty of the quiz?
    1. much more difficult than expected
    2. more difficult than expected
    3. as expected
    4. less difficult than expected
    5. much easier than expected
3. Compared to your ability to do the LTI task items, how would you rate your quiz performance?
    1. much better
    2. better
    3. as expected
    4. a little worse
    5. much worse
4. Which question was the easiest?
5. Which question was the most difficult?
6. How did this week's quiz compare to that from the last LTI?
    1. much easier
    2. a little easier
    3. same level of difficulty
    4. a little harder

5. much harder

7. How did the amount of information covered this week compare to last week?

    1. much less this week

    2. a little less this week

    3. about the same this week

    4. a little more this week

    5. much more this week

8. Compared to last week, how much time did you spend on organic chemistry this week?

    1. much less this week

    2. a little less this week

    3. about the same this week

    4. a little more this week

    5. much more this week

9. Compared to last week, how distracted were you in class this week (by, for example, texting, MSN-ing, fatigue, etc)?

    1. much less this week

    2. a little less this week

    3. about the same this week

    4. a little more this week

    5. much more this week

10. How interesting was the content covered this week compared to last week?

    1. much more interesting

    2. a little more interesting

    3. about the same

    4. a little less interesting

    5. much less interesting

2 Appendix: Selected additional data in support of key findings

The present study summarizes data from several research studies. Given the complexity and breadth of these independent research studies, not all data can be incorporated in the present summary. Some of this research has already been published and refence to those findings is cited as a reference to the published article. Other studies are not yet published. To anchor the results reported below within the body of the manuscript, the relevant Phase of the iterative program is identified. In addition, within each phase the specific statement made in the manuscript that references the reported result is quoted. Note that corroborating analyses to support findings in one Phase are not provided in cases where corroborating evidence was provided in an earlier phase and outcomes reflect a replication of findings.

2.1 Phase II Findings

The major findings reported in Phase II were:

"Surprisingly, there were no differences across condition (primed versus not primed, or massed versus distributed) with respect to number of LTIs completed or exam performance, nor were there differences across the term for the three measures of metacognitive awareness: knowledge of cognition, regulation of cognition, and overall metacognitive awareness."

Sample of analyses in support of these claims:

No differences across condition (primed versus not primed, or massed versus distributed; $F(3, 153) = 0.10$, p = n.s.).

No differences across the term for the three measures of metacognitive awareness: knowledge of cognition ($t_{MK(156)} = .74$, p = n.s.), regulation of cognition ($t_{MR(150)} = -1.39$, p = n.s.), and overall metacognitive awareness ($t_{MTotal(150)} = -1.02$, p = n.s.).

2.2 Phase III Findings

The major findings reported in Phase 3 were:

(1) "Analyses indicated that "skimmed" (response C) was the most frequently endorsed choice among "middle" (final course grade: 60-79.99%) and "bottom" (final course grade: 9.99-59.99%) performers, and 'no access' (response B) was the most frequently endorsed choice among "top" (final course grade: 80 - 100%) performers."

Sample of analyses in support of these claims:

74.9% of the "middle" students responded, with 39.1% of responding students endorsing the "skimmed" response.

55.7% of the "bottom" students responded, with 39.1% of responding students endorsing the "skimmed" response.

78.1% of the "bottom" students responded, with 38.9% of responding students endorsing the "no access" response.

(2) “Although effective use of the inventory cues decreased across the term…”

Sample of analyses in support of these claims:

80.2% of participants responded at the early time point, and 67.2% of participants responded at the late time point. The two most frequently endorsed responses across these two points in the term were “no access” and “skimmed”, with the frequency of “no access” increasing among those responding (early: 23.6% to late: 44.0%) and the frequency of “skimmed” decreasing (early: 39.3% to late: 32.7%).

(3) “Noteworthy is that the effect size for LTIs was larger than for all three prior learning variables (Chemistry 1 and 2 grades and overall GPA)”

Data in support of this claim:

3 prior knowledge variables were entered into a step-wise regression alongside the number of LTIs completed. In each step, beta weights were significant with beta weights for number of LTIs completed (range of β = 1.127 - 1.212) being larger than for each of the three prior knowledge variables (range of β = 0.808 - 1.106).

2.3 Phase IV Findings

The major findings reported in Phase 3 were:

(1) “Major findings from Phase IV include (i) a clear Dunning-Kruger effect across the term for test grade pre- and postdictions, with (a) low-performing students overestimating grades and high-performing students underestimating, (b) the overall effect decreasing over time, both within test and between test, (c) low-achieving students becoming more accurate over time but high-achievers becoming less accurate…”

See Phase III for sample data outcomes for the previous iteration of the course. See introductory comment about not provided supporting data in cases where corroborating evidence was provided in an earlier phase and outcomes reflect a replication of findings.

(2) “…day of predictions and postdictions being significant predictors of actual test scores…”

Sample of analyses in support of these claims:

For example, linear regression analysis demonstrated that prediction and postdiction scores predicted final exam scores, ($F(3,140) = 45.18$, $p < 0.001$).