Biochemistry and Molecular Biology

Note: Assessment tools on student views about science and specific disciplines of science can be found in Student Views/Attitudes/Affective Instruments.

Expected Biology and Chemistry Foundational Concepts

This survey is a multiple-choice instrument intended to measure five concepts from general chemistry and three from biology that are considered prerequisite for biochemistry learning.

Sachel M Villafañe, Cheryl P Bailey, Jennifer Loertscher, Vicky Minderhout, Jennifer E Lewis. Biochemistry and Molecular Biology Education, 39 (2), pp. 102-109 (2011). DOI: 10.1002/bmb.20464

Sachel M. Villafane, Jennifer Loertscher, Vicky Minderhout and Jennifer E. Lewis. Chemical Education Research Practices, 12, pp. 210-218 (2011). DOI: 10.1039/C1RP90026A

Enzyme–Substrate Interactions Concept Inventory (ESICI)

This 15-item inventory that measures student understanding of enzyme–substrate interactions.

Stacey Lowery Bretz and Kimberly J. Linenberger. Development of the enzyme-substrate interactions concept inventory. Biochemistry and Molecular Biology Education. 40(4) pp. 229-233, 2012.

Molecular Life Sciences Concept Inventory (MLSCI)

This concept inventory is intended to assess dynamic equilibrium, macromolecular structure, energy transformations, information coding, catalysis and cellular compartmentalization.

Tony Wright, Susan Hamilton, Mary Rafter, Susan Howitt, Trevor Anderson and Manuel Costa. Assessing student understanding in the molecular life sciences using a concept inventory. FASEB J. 23 (Meeting abstract supplement) LB307, April 2009.

Susan Howitt, Trevor Anderson, Manuel Costa, Susan Hamilton, and Tony Wright. A concept inventory for the life sciences: How will it help your teaching practice? Aust Biochem. 39: 14-17, 2008.

Taxonomy of biochemistry external representations (TOBER)

The Taxonomy of Biochemistry External Representations (TOBER) is proposed as a method for classifying the types of ERs used in biochemistry classrooms.

Marcy H. Towns, Jeffrey R. Raker, Nicole Becker, Marissa Harle, and Johnathan Sutcliffe. The biochemistry tetrahedron and the development of the taxonomy of biochemistry external representations (TOBER). Chemistry Education Research Practice, 13, pp. 296-306.

Biology

Primary Source: Concept Inventories/Conceptual Assessments in Biology (CABs) website.

http://go.sdsu.edu/dus/ctl/cabs.aspx

Molecular and Cell Biology, Genetics

Biology Concept Inventory (BCI)

Thirty questions to ssesses understanding of general biology concepts. Field-tested with introductory major's biology students. Items provided at: http://bioliteracy.colorado.edu/

Klymkowsky MW, Garvin-Doxas K, Zeilik M. 2003. Bioliteracy and teaching efficacy: What biologists can learn from physicists. Cell Biology Education 2: 155-161.

Garvin-Doxas K, Klymkowsky MW, Elrod S. 2007. Building, using, and maximizing the impact of concept inventories in the biology education: Report on a National Science Foundation–sponsored conference on the construction of concept inventories in the biological sciences. CBE Life Science Education 6: 277-282.

Klymkowsky M.W., K. Garvin-Doxas. 2008. Recognizing students' misconceptions through Ed's tools and the Biology Concept Inventory. PloS Biology 6: e3.

Garvin-Doxas K, Klymkowsky MW. 2008. Understanding randomness and its impact on student learning: Lessons learned from building the Biology Concept Inventory (BCI). CBE Life Science Education 7: 227–233.

Garvin-Doxas K, Doxas I, Klymkowsky MW. 2008. Ed's Tools: A web-based software toolset for accelerated concept inventory construction. pp 130-140. In: Deeds, D & B Callen, editors; Proceedings of the National STEM Assessment Conference. Washington DC, October 19-21, 2006.

Introductory Molecular and Cell Biology Assessment (IMCA)

Assesses general concepts from molecular and cellular biology. Field-tested with introductory molecular biology majors. (24 MC items, diagrams)

Shi J, Wood WB, Martin JM, Guild NA, Vicens Q, Knight JK. 2010. A diagnostic assessment for introductory molecular and cell biology. CBE Life Sciences Education 9: 453-461. Items provided at: http://w.lifescied.org/content/9/4/453.full

Molecular Life Sciences Concept Inventory (MLS)

Assesses concepts related to molecular structure, dynamics, and energy (26 MC items in trial reported in Wright and Hamilton 2008; 96 MC items addressing 10 “big ideas” in 6 modules on-line, diagrams, scenarios).

Howitt S, Anderson T, M, Hamilton S, Wright T. 2008. A concept inventory for molecular life sciences: How will it help your teaching practice? Australian Biochemist 39: 14-17.

Wright T, Hamilton S. 2008. Assessing student understanding in the molecular life sciences using a concept inventory. In: Duff A, Green M, Quinn D, ATN Assessment Conference Proceedings. Australian Technology Network (ATN) Assessment Conference: Engaging Students in Assessment, Adelaide, South Australia (pp 216-224). Nov. 20-21, 2008.

Diffusion and Osmosis Diagnostic Test (DODT)

Assesses concepts related to diffusion and osmosis. Field-tested with secondary students as well as introductory majors and nonmajors biology students (12 two-tiered MC items, diagrams). Items provided at: umdberg.pbworks.com/f/Odom1995-DiffusionMisconceptions.pdf

Odom AL, Barrow LH. 1995. The development and application of a two-tiered diagnostic test measuring college biology students' understanding of diffusion and osmosis following a course of instruction. Journal of Research in Science Teaching 32: 45-61.

Odom AL. 1995. Secondary and college biology students' misconceptions about diffusion and osmosis. American Biology Teacher 57: 409–415.

Osmosis and diffusion conceptual assessment (ODCA)

Assesses concepts related to diffusion and osmosis. Field-tested with introductory nonmajors as well as introductory and upper-division biology majors. Includes components of previously published DODT (8 two-tiered MC items, diagrams). Items provided at: http://www.lifescied.org/content/10/4/418.full.pdf+html?with-ds=yes

Fisher KM, Williams KS, Lineback J. 2011. Osmosis and diffusion conceptual assessment. CBE Life Sciences Education 10: 418-29. doi: 10.1187/cbe.11-04-0038.

Meiosis Concept Inventory (Meiosis CI)

Assesses understanding of concepts and processes of meiosis. Field-tested with introductory biology and genetics students (17 questions, mixed MC, MC select all). Items available at:
http://q4b.biology.ubc.ca

Kalas P, O'Neill A, Pollock C, Birol G. (2013). Development of a meiosis concept inventory. CBE Life Sci Educ 12, 655–664.

Genetics Literacy Assessment Instrument (GLAI)

Thirty-one questions to assess assorted concepts in genetics and inheritance. Field-tested with introductory majors and non-majors biology students. Items provided in Moskalik 2007:
https://etd.ohiolink.edu/ap/10?0::NO:10:P10_ACCESSION_NUM:ucin1195583851

Bowling BV, Acra EE, Wang L, Myers MF, Dean GE, Markle GC, Moskalik CL, Huether CA. 2008. Development and evaluation of a genetics literacy assessment instrument for undergraduates. Genetics 178: 15-22.

Bowling BV, Huether CA, Wang L, Myers MF, Markle GC, Dean GE, Acra EE, Wray FP, Jacob GA. 2008. Genetic literacy of undergraduate non-science majors and the impact of introductory biology and genetics courses. BioScience 58: 654-660.

Moskalik CL. 2007. I. Impact of a Genetics Education Workshop on Faculty Participants II. Investigations of Undergraduate Genetic Literacy. Thesis (M.S.), University of Cincinnati, Cincinnati OH, Arts and Sciences: Biological Sciences, 2007. Called Genetics Literacy Concept Inventory (GLCI).

Genetics Concept Assessment (GCA)

Twenty-five multiple choice questions to assess general concepts in genetics and inheritance. Field-tested with majors and non-majors genetics students.

Reference: Smith MK, Wood WB, Knight JK. 2008. The genetics concept assessment: A new concept inventory for gauging student understanding of genetics CBE Life Science Education 7: 422-430.

Genetics Diagnostic Instrument

Assesses general concepts in genetics and inheritance. Field-tested with upper-level secondary students (13 two-tiered MC items, diagrams). Items provided at: http://www.tandfonline.com/doi/pdf/10.1080/09500690902951429#.U8w9nrF33QA

Reference: Tsui CY, Treagust D. 2009. Evaluating secondary students' scientific reasoning in genetics using a two-tier diagnostic instrument. International Journal of Science Education 32: 1073-1098.

Physiology and Organismal Systems

Developmental Biology Content Survey

Assesses general concepts in developmental biology. Field-tested with upper-division developmental biology students (15 MC items). Items provided at: http://www.lifescied.org/content/4/4/298

Knight JK, Wood WB. 2005. Teaching more by lecturing less. Cell Biology Education 4: 298-310.

Host-Pathogen Interactions (HPI)

Assesses understanding of host-pathogen interactions. Field-tested with introductory, intermediate, and advanced students from a microbiology program (17 [18 noted in Marbach-Ad et al. 2009] two-tiered MC items).

Marbach-Ad G, Briken V, El-Sayed NM, Frauwirth K, Fredericksen B, Hutcheson S, Gao L-Y, Joseph SW, Lee V, McIver KS, Mosser D, Quimby BB, Shields P, Song W, Stein DC, Yuan RT, Smith AC. 2009. Assessing student understanding of host pathogen interactions using a concept inventory. Journal of Microbiology Education 10: 43-50.

Marbach-Ad G, McAdams KC, Benson S, Briken V, Cathcart L, Chase M, El-Sayed NM, Frauwirth K, Fredericksen B, Joseph SW, Lee V, McIver KS, Mosser D, Quimby BB, Shields P, Song W, Stein DC, Stewart R, Thompson KV, Smith AC. 2010. A model for using a concept inventory as a tool for students' assessment and faculty professional development. CBE Life Science Education 9: 408-416.

Breathing and Respiration

Assesses understanding of breathing, gas exchange, and respiration through a paper-pencil format. Field tested with secondary students (12 two-tiered MC items).

Reference: Mann M, Treagust DF. 1998. A pencil and paper instrument to diagnose students' conceptions of breathing, gas exchange and respiration. Australian Science Teachers Journal 44: 55–59.

Photosynthesis and Respiration

Assesses understanding of photosynthesis and respiration in plants. Field-tested with secondary students (13 two-tiered MC items, plus open ended).

Reference: Haslam F, Treagust DF. 1987. Diagnosing secondary students' misconceptions of photosynthesis and respiration in plants using a two-tier multiple choice instrument. Journal of Biological Education 21: 203–211.

Flowering Plant Growth and Development

Assesses understanding of flowering plant growth and development. Field-tested with secondary students (13 two-tiered MC items). Items provided at: www.lifescied.org/content/4/4/298

Reference: Lin SW. 2004. Development and application of a two-tier diagnostic test for high school students' understanding of flowering plant growth and development. International Journal of Science and Mathematics Education 2: 175–199.

Internal Transport in Plants and the Human Circulatory Systems

Assesses concepts related to transport in plants and the human circulatory system. Three test versions were developed and field-tested for elementary, secondary, and undergraduate students. (28 two-tiered MC items).

Reference: Wang JR. 2004. Development and validation of a two-tier instrument to examine understanding of internal transport in plants and the human circulatory system. International Journal of Science and Mathematics Education 2: 131–157.

Evolution and Ecology

Conceptual Inventory of Natural Selection (CINS)

Assesses student understanding of natural selection using actual scientific studies. Field-tested with non-majors biology students (20 MC items, scenarios). Items provided at: http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB0QFjAA&url=http%3A%2F%2Fbioliteracy.colorado.edu%2FReadings%2FNatural%2520Selection%2520CI.pdf&ei=rirMU_2wH8uoyAS70oHABg&usg=AFQjCNHer5OD_cVxHba7OAN-sltpeVaLzw&bvm=bv.71198958,d.aWw

References: Anderson DL, Fisher KM, Norman JG. 2002. Development and validation of the conceptual inventory of natural selection. Journal of Research in Science Teaching 39: 952-978.

Anderson DL. 2003. Natural selection theory in non-majors' Biology: instruction, assessment, and conceptual difficulty. Thesis (Ph.D.) University of California, San Diego and San Diego State University, San Diego, CA.

Natural Selection instrument

Assesses understanding of natural selection using a paper and pencil format. Field-tested with introductory biology students (6 open-ended questions).

References: Nehm, R.H. & Reilly, L. (2007) Biology majors' knowledge and misconceptions
of natural selection. BioScience 57, 263-272

Measure of Understanding of Macroevolution (MUM)

Assesses macroevolutionary concepts, including deep time, phylogenetics, speciation, fossils, and nature of science. Field-tested with introductory and capstone-level students (28 items: 27 MC items, plus one open-ended item, diagrams). Items provided at: http://www.researchgate.net/publication/233108952_Development_and_Preliminary_Evaluation_of_the_Measure_of_Understanding_of_Macroevolution_Introducing_the_MUM/file/72e7e527280a65d52f.pdf

Nadelson LS, Southerland SA. 2010. Development and preliminary evaluation of the Measure of Understanding of Macroevolution: Introducing the MUM. The Journal of Experimental Education 78: 151–190.

Basic Tree Thinking Assessment

Assesses interpretation of evolutionary relationships depicted on phylogenetic tree diagrams. There are two tests, 10 multiple choice items each with diagrams. Items provided at:
http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0CCgQFjAB&url=http%3A%2F%2Fwww.evolution.wisc.edu%2Fsites%2Fdefault%2Ffiles%2FBasic%2520Tree%2520Thinking%2520Assessment.pdf&ei=8C7MU5iAEcSxyAS3yoKQBA&usg=AFQjCNFIJ3wqb9L5gkYpV4sHc12VfiehlQ&bvm=bv.71198958,d.aWw

Reference: Baum DA, Smith SD, Donovan SSS. 2005. The tree-thinking challenge. Science 310: 979-980.

Phylogeny Assessment Tool (PhAT)

A three-part instrument assessing understanding of the relationship between organism characteristics and evolutionary relationships. Field-tested with introductory organismal biology students. The assessment includes 3 open-ended questions, diagram). Instrument provided at:
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3763020/

References: Smith JJ, Cheruvelil KS, Auvenshine S. 2013. Assessment of Student Learning Associated with Tree Thinking in an Undergraduate Introductory Organismal Biology Course. CBE-Life Sciences Education 12:542-552.

Genetic Drift Inventory (GeDI)

Assesses concepts related to evolution with a particular focus on genetics drift. Field-tested with upper-division biology students (22 agree-disagree items). Items provided at: http://www.lifescied.org/content/13/1/65.full

References: Andrews TM, Price RM, Mead LS, McElhinny TL, Thanukos A, Perez KE, Herreid CF, Terry DR, Lemons PP. 2012. Biology Undergraduates' Misconceptions about Genetic Drift. CBE Life Science Education 11: 248-259.

Price RM, Andrews TC, McElhinny TL, Mead LS, Abraham JK, Thanukos A, Perez KE. 2014. The Genetic Drift Inventory: A tool for measuring what advanced undergraduates have mastered about genetic drift. CBE Life Science Education 13: 65-75.

EvoDevo Concept Inventory (EvoDevoCI)

Assesses developmental aspects of evolution. Field-tested with biology majors. Multiple choice and open ended items for 3 Exploratory Surveys and 6 Interview Question sets. Eleven multiple choice items, 4 scenarios. Items provided at:
www.lifescied.org/content/12/3/494 and http://www.lifescied.org/content/12/4/665

References: Hiatt A, Davis GK, Trujillo C, Terry M, French DP, Price RM, Perez KE. 2013. Getting to Evo-Devo: Concepts and challenges for students learning evolutionary developmental biology. CBE Life Sciences Education 12: 494-508. doi:10.1187/cbe.12-11-0203. [PDF available] from lifescied.

Perez KE, Hiatt A, Davis GK, Trujillo C, French DP, Terry M, and Price RM. 2013. The EvoDevoCI: A Concept inventory for gauging students' understanding of evolutionary developmental biology. CBE Life Sciences Education 12: 665-675.

Energy and Matter

Diagnostic Question Clusters on Energy and Matter (DQCs)

Assesses understanding of pathways and transformations of energy and matter within the context of biological systems. Field-tested with introductory through advanced-level biology students (16 DQC sets of ~7 items each, MC, TF, open-ended). Items available at: http://www.biodqc.org/downloads

References: Wilson CD, Anderson CW, Heidemann M, Merrill JE, Merritt BW, Richmond G, Silbey DF, Parker JM. 2006. Assessing students' ability to trace matter in dynamic systems in cell biology. CBE Life Sciences Education 5: 323–331.

Hartley LM, Wilke BJ, Schramm JW, D'Avanzo C, Anderson CW. 2011. College students' understanding of the carbon cycle: contrasting principle-based and informal reasoning. BioScience 61: 65-75.

D'Avanzo C, Anderson CW, Griffith A, Merrill J. 2011. Thinking like a biologist. Using diagnostic questions to help students reason with biological principles.

Note: Assessment tools on student views about biology can be found in Student Views/Attitudes/Affective Instruments.

Chemistry

General Chemistry

Chemistry Competence Test (CCT)

This is a diagnostic test developed initially to document proficiencies of first-time entering students to South African universities and has proved to be a versatile instrument for multiple uses.

Marietjie Potgieter and Bette Davidowitz. Preparedness for tertiary chemistry: multiple applications of Chemistry Competence Test for diagnostic and prediction purposes. Chemistry Education Research Practices 12, pp. 193-204, 2011.

Chemistry Reasoning Test (CRT)

This instrument was designed to be an easy-to-use tool for measuring conceptual understanding and critical scientific thinking of general chemistry models and theories.

Carrie A. Cloonan and John S. Hutchinson. A Chemistry Concept Reasoning Test. Chemistry Education Research Practices. 12, pp. 205-209, 2011. DOI: 10.1039/C1RP90025K.

Chemistry Concept Inventory (ChCI)

The ChCI assesses thermochemistry, bonding, intermolecular forces, equilibrium, acids and bases, and electrochemistry. Thirty of the sixty questions for the first semester of a two-semester chemistry course, and the other thirty are for the second semester of the course. Please contact Jim Birk at Arizona State University about this inventory.

J. Birk, B. Jenkins, R. Bauer, S. Krause, M. Pavelich, *Development and Application of a Chemistry Concept Inventory*, Symposium on Research in Chemistry Education, 227th National Meeting of the American Chemical Society, Anaheim, CA, (2004).

Chemistry Concept Inventory (CCI)

The questions are based on common commonly observed student misconceptions about topics generally covered in the first semester of a college chemistry course. The inventory can be found at http://www.jce.divched.org/jcedlib/qbank/collection/CQandChP/CQs/ConceptsInventory/Concepts_Inventory.html.

Mulford DR and Robinson WR (2002) An inventory for alternate conceptions among 1st semester general chemistry students. J Chem Ed 79: 739-744.

Journal of *Chemical Education* On-Line: Library of Conceptual Questions. American Chemical Society Division of Chemical Education. 13 December 13 2001.

Jack Barbera, A Psychometric Analysis of the Chemical Concepts Inventory. J. Chemical Education, 90 (5), pp. 546-553 (2013). DOI**:** 10.1021/ed3004353

Solution Chemistry

This two-tier diagnostic instrument is designed to test 16-17 year-old students' understanding of solution chemistry concepts.

Ermine Adadan and Funda Savasci. An analysis of 16-17 year-old students' understanding of solution chemistry concepts using a two-tier diagnostic instrument. International Journal of Science Education 34(4), 2012.

Organic Chemistry

Acid Strength

This instrument is a nine-item multiple-tier, multiple-choice concept inventory to identify alternative conceptions that organic chemistry students hold about acid strength, to determine the prevalence of these conceptions, and to determine how strongly these conceptions bias student reasoning.

LaKeisha M. McClary and Stacey Lowery Bretz. Development and Assessment of a diagnostic tool to identify organic chemistry students' alternative conceptions related to acid strength. International Journal of Science Education 34(15), 2012.

Thermodynamics

Thermodynamics Concept Inventory (TCI)

The TCI is intended for use in introductory thermodynamics courses. Please contact Clark Midkiff at the University of Alabama about this inventory.

Midkiff, K.C., Litzinger, T.A., and Evans, D.L., "Development of Engineering Thermodynamics Concept Inventory Instruments," *Proceedings,* Frontiers in Education Conference, Reno, Nevada, 10–13 October 2001.

Introductory Thermal Concept Evaluation (ITCE)

Developed to assess a wide range of beliefs or understandings about thermodynamic concepts in 15-18 year old students. Administered in less than 30 minutes.

Shelly Yeo and Marjan Zadnik. Introductory Thermal Concept Evaluation: Assessing Students' Understanding. The Physics Teacher, Volume 39, 2001.

Quantum Mechanics

The Quantum Mechanics Visualization Instrument (QMVI)

The QMVI is designed to assess student's understanding of core concepts in introductory quantum mechanics. It is available by contacting Richard Robinett at Penn State.

Description of the development of the instrument is found in Erdat Cataloglu's dissertation (https://etda.libraries.psu.edu/paper/5937/**).**

Quantum Mechanics Survey (QMS)

This survey is designed to evaluate student's conceptual understanding of quantum mechanics in junior-level courses. It is available after obtaining a password via http://perusersguide.org/items/detail.cfm?ID=11903.

Chandralekha Singh and Guangtian Zhu. *Surveying students' understanding of quantum mechanics in one spatial dimension*, Am. J. Phys. **80** (3), 252-259.

Quantum Mechanics Conceptual Survey (QMCS)

This twelve question survey is designed to assess students' conceptual understanding of quantum mechanics.

S.B. McKagan, K.K. Perkins and C.E. Wieman. Design and validation of Quantum Mechanics Conceptual Survey. Physics Education Research 6, 020121 (2010) DOI: 10.1103/PhysRevSTPER.6.020121

Quantum Mechanics Assessment Tool (QMAT)

This assessment was developed to (1) reflect faculty learning goals, provide an assessment of student learning difficulties, and act as a tool to help guide faculty efforts at improving QM instruction. Contact Steve Pollack at University of Colorado.

Steve Goldhaber, Steven Pollack, Paul Beale and Katherine Perkins. Transforming Upper-Division Quantum Mechanics: Learning Goals and Assessment. American Institute of Physics Conference Proceedings 1179, 145 (2009). doi: 10.1063/1.3266699.

Note: Assessment tools on student views about chemistry can be found in Student Views/Attitudes/Affective Instruments

Math

Calculus Concept Inventory

Assesses the most basic principles of differential calculus. Field-tested with undergraduate students in Calculus I.

Epstein J. The Calculus Concept Inventory—Measurement of the Effect of Teaching Methodology in Mathematics. Notices of the AMS 60:1018-1026.

Precalculus Concept Assessment (PCA)

This 25-item multiple choice instrument measures the reasoning abilities and understandings foundations, which includes strong understanding of ideas of rate of change and function, a process view of function, and the ability to use covariational

reasoning to examine and represent how two covarying quantities change together. The uses of PCA include (a) assessing student learning in college algebra and precalculus, (b) comparing the effectiveness of various curricular treatments, and (c) determining student readiness for calculus. https://mathed.asu.edu/instruments/PCA/index.shtml
Reference: Carlson M, Oehrtman M, and Engelke N (2010) The precalculus concept assessment: A tool for assessing students' reasoning abilities and understandings. Cognition and Instruction 28(2): **113-145. DOI:**10.1080/07370001003676587

Math Skills Inventory

A 34 item self-assessment survey of behaviors that can be used to optimize performance in courses requiring quantitative skills.
http://www.uaf.edu/deved/math/help-for-math-anxiety/math-skills-inventory/
http://capone.mtsu.edu/studskl/mathsurvey2.html

Quadratic and Linear Conceptual Evaluation (QLCE)

Assesses basic mathematical modeling skills when a quadratic function is used to model a kinematic phenomenon under different circumstances and gauges student understanding of the relationship between graphs and changes in linear equation coefficients and vice versa (40 items, some questions are matrix-like and require 5 answers each). Items available at:
http://physics.dickinson.edu/~wp_web/wp_resources/wp_assessment.html#MPEX

References: Publications associated with this instrument were not identified.

Vector Evaluation Test (VET)

Assesses vector analysis skills, including addition and subtraction, component analysis, and comparing magnitudes (31 multiple-choice and short-answer items). Items available at:
http://physics.dickinson.edu/~wp_web/wp_resources/wp_assessment.html#MPEX

References: Publications associated with this instrument were not identified.

Note: Assessment tools on student views about math can be found in Student Views/Attitudes/Affective Instruments.

Physics

Generation of this list of concept inventories relied information found at http://www.ncsu.edu/per/TestInfo.html. More inventories can be found there.

Force

Force Concept Inventory (FCI)

A physics and mathematics diagnostic test originally developed in 1985 and revised in 1995. Recommended use (1) as a placement exam, (2) to evaluate instruction, (3) as a diagnostic test. Access to the test is available at http://modeling.asu.edu/R%26E/Research.html.

I. Halloun and D. Hestenes, The Initial Knowledge State of College Physics Students, Am. J. Phys. 53: 1043-1055 (1985) and I Halloun and D. Hestenes, Common Sense Concepts about Motion, *Am. J. Phys*. 53: 1056-1065 (1985).

D. Hestenes and I. Halloun, Interpreting the FCI. The Physics Teacher 33: 502-506 (1995).

The Force and Motion Conceptual Evaluation (FMCE)

Assess student's conceptual understanding of Newton's Laws of Motion. Publication describes assessment of an introductory physics class.

R. Thornton, and D. Sokoloff, (1998) Assessing student learning of Newton's laws: The Force and Motion Conceptual Evaluation and the Evaluation of Active Learning Laboratory and Lecture Curricula, Am. J. Phys., 66, Issue 4, 338-352.

Rotational and Rolling Motion Conceptual Survey (RRMCS)

A 30-question research-based multiple-choice test is designed to evaluate students' conceptual understanding of rotational and rolling motion and can be found at: http://www.compadre.org/per/items/detail.cfm?ID=11956.

Lorenzo G. Rimoldini and Chandralekha Singh (2005) Student understanding of rotational and rolling motion, Phys. Rev ST-PER **1** (1), 010102.

Alexandru Maries and Chandralekha Singh (2005) Exploring Pedagogical Content Knowledge of Physics Instructors and Teaching Assistants Using the Force Concept Inventory. Phys. Rev ST PER 1, 010102 (2005). Doi: 10.1103/PhysRevSTPER.1.010102.

Graphing and Representations

Representational Variant of the Force Concept Inventory

Investigates students' ability to interpret multiple representations consistently (e.g., motion map, vectorial, and graphical). Available at http://www.compadre.org/per/items/detail.cfm?ID=11958.

P. Nieminen, A. Savinainen and J. Viiri (2010) Force Concept Inventory-based multiple-choice test for investigating students' representational consistency" Phys. Rev. ST Physics Ed. Research 6, 020109.

Test of Understanding Graphs in Kinematics (TUG-K)

A measure of students' ability to interpret kinematics graphs.

R. Beichner (1994) Testing student interpretation of kinematics graphs" Am. J. Phys., 62, 750-762.

Energy

The Energy and Momentum Conceptual Survey (EMCS)

Assesses concepts in energy and momentum and can be found at http://www.compadre.org/per/items/detail.cfm?ID=11896.

Reference: C. Singh and D. Rosengrant, Multiple-choice test of energy and momentum concepts, Am. J. Phys. 71 (6), 607-619 (2003).

The Energy Concept Assessment (ECA)

Evaluates students' understanding of various energy related topics. Created for a calculus-based introductory physics course. Contact Lin Ding at Ohio State University.

Reference: Dissertation http://www.lib.ncsu.edu/resolver/1840.16/4050

Thermodynamics

Thermodynamics Concept Inventory (TCI)

The TCI is intended for use in introductory thermodynamics courses. Please contact Clark Midkiff at the University of Alabama about this inventory.

Reference: Midkiff, K.C., Litzinger, T.A., and Evans, D.L., "Development of Engineering Thermodynamics Concept Inventory Instruments," Proceedings, Frontiers in Education Conference, Reno, Nevada, 10–13 October 2001.

Introductory Thermal Concept Evaluation (ITCE)

Developed to assess a wide range of beliefs or understandings about thermodynamic concepts in 15-18 year old students. Administered in less than 30 minutes.

Reference: Shelly Yeo and Marjan Zadnik (2001) Introductory Thermal Concept Evaluation: Assessing Students' Understanding. The Physics Teacher, Volume 39.

The Heat and Energy Concept Inventory (HECI)

A 36 multiple-choice question inventory for an undergraduate heat transfer course of (1) temperature vs. energy, (2) temperature vs. perceptions of hot and cold, (3) factors that affect the rate vs. amount of heat transfer, (4) thermal radiation.

Reference: Michael Prince, Margo Vigeant, Katharyn Nottis (2012) Development of the Heat and Energy Concept Inventory: Preliminary Results on the Prevalence and Persistence of Engineering Students' Misconceptions. Journal of Engineering Education, Volume 101(3):412-438.

The Heat and Temperature Concept Evaluation (HCTE)

Survey on heat, temperature and heat flow. A 28 inventory that takes 30-40 minutes to complete. Twenty-seven items are machine graded and one item requires drawing a graph and writing a sentence.

Reference: Thornton R and Sokoloff D (1987) The Heat and Temperature Concept Evaluation (HCTE)
http://physics.dickinson.edu/~wp_web/wp_resources/wp_assessment.html#HTCE

Heat Transfer Concept Inventory (HTCI)

Assesses student understanding of concepts, identifies misunderstandings, provides feedback to instructors, and evaluates student gains in a heat transfer course. The HTCI is being evaluated for coverage; concepts include fundamental ideas, conduction, convection, and radiation. Contact Jay Marin at University of Wisconsin-Madison.

Reference: Jay Martin, John Mitchell, Ty Newell. A concept inventory for Heat Transfer. Session 33rd ASFEE/IEEE Frontiers in Education Conference T3D-12. November 5-8, Boulder (2003).

Thermal and Transport Concept Inventory (TTCI)

Faculty and students use the Thermal and Transport concept inventory (TTCI) assessment instrument to identify fundamental misconceptions about heat transfer, fluid mechanics, and thermodynamics in engineering students. Contact Ron Miller at Colorado School of Mines.

References: Ruth A. Streveler, Ronald L. Miller, Aidsa I. Santiago Roman, Mary A. Nelson, Monica R. Geist, Barbara M. Olds, "Rigorous Methodology for Concept Inventory Development: Using the 'Assessment Triangle' to Develop and Test the Thermal and Transport Science Concept Inventory (TTCI)", International Journal of Engineering Education Vol. 27, No. 5, pp. 968–984, 2011 0949-149X/91.

Waves

Waves Concept Inventory (WCI)

Assesses visualization of waves, mathematical depiction of waves, and wave definitions. The WCI allows more than one correct choice for most of the questions. Choosing more than one answer correlates with increasing understanding of the material. The WCI is intended for junior-level electronics of materials courses. Contact Ron Roedel at Arizona State University.

References: Roedel, R.J., El-Ghazaly, S., Rhoads, T.R., and El-Sharawy, E., "The Wave Concepts Inventory—An Assessment Tool for Courses in Electromagnetic Engineering," *Proceedings,* Frontiers in Education Conference, November 1998, Tempe, AZ.

Rhoads, T.R., Roedel, R.J., "The Wave Concept Inventory—A Cognitive Instrument Based on Bloom's Taxonomy," *Proceedings,* Frontiers in Education Conference, San Juan, Puerto Rico, 10–13 November 1999.

Wave Diagnostic Test (WDT)

The University of Maryland WDT investigates student difficulties with wave physics at the introductory level. Contact Janice Redish at University of Maryland.

Reference: Janice Redish, Making Sense of What Happens in Physics Classes: Analyzing Student Learning. American Physics Society Centennial Lecture, presented at APS/AAPT joint meeting, Atlanta, GA, 24 March, 1999.

Electricity

Circuits (CCI)

Part I measures students' conceptual understanding of the basic properties of electricity, circuit components, and linear time-invariant networks (DC and AC). Part II addresses frequency domain concepts, coupled inductors, convolution, impulse response, and transform techniques. Contact Robert Helgeland at University of Massachusetts at Dartmouth.

Helgeland, B., & Rancour, D. (2013). Circuits Concept Inventory. Retrieved from http://www.foundationcoalition.org/home/keycomponents/concept/circuits.html

Electromagnetics (EMCI)

EMCI Version 1.0 is composed of three instruments: (i) Fields (electro and magnetostatic, and time-varying EM fields), (ii) Waves (uniform plane waves, transmission lines, waveguides, and antennas), (iii) Fields and Waves (combination of the first two instruments). Contact Branislav Notaros at University of Colorado.

Notaros, B.M. (2002). “Concept Inventory Assessment Instruments for Electromagnetic Education,” Proceedings, IEEE Antennas and Propagation Society International Symposium, San Antonio, Texas

Electronics (ECI)

The 35-question ECI assesses student understanding of introductory electronics concepts that are covered in the first of a two-course sequence. The exam includes a small subset of basic circuit analysis questions so that instructors can differentiate between misconceptions in circuit analysis and misconceptions in electronics. Contact Marc Herniter at Rose-Hulman Institute of Technology.

M.F. Simoni, M.E. Herniter, and B.A. Ferguson. Concepts to Questions: Creating an Electronics Concept Inventory Exam. Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition, Session 1793.

Quantum Mechanics

The Quantum Mechanics Visualization Instrument (QMVI)

The QMVI is designed to assess student’s understanding of core concepts in introductory quantum mechanics. It is available by contacting Richard Robinett at Penn State.

Description of the development of the instrument is found in Erdat Cataloglu’s dissertation **(**https://etda.libraries.psu.edu/paper/5937/**).**

Quantum Mechanics Survey (QMS)

This survey is designed to evaluate student’s conceptual understanding of quantum mechanics in junior-level courses. It is available after obtaining a password via http://perusersguide.org/items/detail.cfm?ID=11903.

Chandralekha Singh and Guangtian Zhu. Surveying students' understanding of quantum mechanics in one spatial dimension, Am. J. Phys. 80 (3), 252-259.

Quantum Mechanics Conceptual Survey (QMCS)

This twelve question survey is designed to assess students’ conceptual understanding of quantum mechanics.

S.B. McKagan, K.K. Perkins and C.E. Wieman. Design and validation of Quantum Mechanics Conceptual Survey. Physics Education Research 6, 020121 (2010) DOI: 10.1103/PhysRevSTPER.6.020121

Quantum Mechanics Assessment Tool (QMAT)

This assessment was developed to (1) reflect faculty learning goals, provide an assessment of student learning difficulties, and act as a tool to help guide faculty efforts at improving QM instruction. Contact Steve Pollack at University of Colorado.

Steve Goldhaber, Steven Pollack, Paul Beale and Katherine Perkins. Transforming Upper-Division Quantum Mechanics: Learning Goals and Assessment. AIP Conference Proceedings 1179, 145 (2009). doi: 10.1063/1.3266699.

Astronomy

Astronomy Diagnostic Test (ADT)

This diagnostic survey for undergraduate, non-science majors taking their first astronomy course. The first 21 questions are the content portion of the test, while the final 12 questions collect demographic information. Please contact Grace Deming at University of Maryland.

T.F. Slater, B. Hufnagel, and J.P. Adams. Validating the Astronomy Diagnositics Test for Undergraduate Non-Science Majors. American Astronomical Society, 194th AAS Meeting, #70.03; Bulletin of the American Astronomical Society, Vol. 31, p.937.

Astronomical Misconceptions Survey (AMS)

Developed for identifying student misconceptions in astronomy in introductory courses.

Michael C. LoPresto and Steven R. Murrell. An Astronomical Misconceptions Survey. Journal of College Science Teaching, v40 n5 p14-22, May 2011. ISSN-0047-231X.

Newtonian Gravity Concept Inventory (NGCI)

Kathryn E. Williamson, Shannon Willoughby, Edward E. Prather. Development of the Newtonian Gravity Concept Inventory. Astronomy Education Review, v. 12, n.1 (2013). DOI: 10.3847/AER2012045

Lunar Phases Concept Inventory (LPCI)

The Lunar Phases Concept Inventory (LPCI) was developed to aid instructors in assessing students' mental models of lunar phases. Contact Rebecca Lindell at Southern Illinois University.

Rebecca S. Lindell and James P. Olsen. Proceedings of the 2002 Physics Education Research Conference, ed. By S. Franklin, J. Marx and K. Cummings, PERC Publishing, NY, 2002.

Star Properties Concept Inventory (SPCI)

This concept inventory covers the areas of stellar properties (focusing primarily on mass, temperature, luminosity, and lifetime), nuclear fusion, and star formation with distractors from known misconceptions of these areas.

Janelle M. Bailey, Bruce Johnson, Edward E. Prather, Timothy F. Slater. Development and Validation of the Star Properties Concept Inventory.

Space Physics Concept Inventory

Doxas, M. Klymkowski, K. Garvin-Doxas, and C. Willis. Developing a Space Physics Concept Inventory. American Geophysical Union, Spring Meeting 2005, abstract #ED11A-06.

Note: Assessment tools on student views about physics can be found in Student Views/Attitudes/Affective Instruments.

Nature of Science

Views of the Nature of Science (VNOS)

Assesses understanding of the nature of science: that is science is empirical, tentative, inferential, creative, collaborative, theory based, and a product of the larger social and cultural milieu. VNOS-B and VNOS-C can be accessed at http://www.flaguide.org/tools/diagnostic/views_of_nature_questionnaire.php.

Reference: Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learner's conceptions of nature of science. *Journal of Research in Science Teaching*, 39(6), 497-521.

Views on Science and Education (VOSE)

Assesses attitudes towards, knowledge of, and teaching practices related to the nature of science.

Reference: Chen, (2006). Development of an Instrument to Assess Views on Nature of Science and Attitudes Toward Teaching Science. Science Education, 90, 803-819.

Note: These instruments are technically not considered concept inventories. They measure understanding and knowledge of nature of science.