

DEVELOPMENT OF A CONCEPT INVENTORY FOR FLUID MECHANICS

Jay Martin¹, John Mitchell², and Ty Newell³

Abstract - Concept inventories are assessment tools designed to determine the degree to which students understand the concepts of a subject and to identify the misconceptions that students hold. The results of a concept inventory can be used to change the methods of instruction to overcome student misconceptions. A cooperative effort between Mechanical Engineering faculty at the Universities of Wisconsin-Madison and Illinois, Champaign-Urbana has been directed toward development of a Fluid Mechanics Concept Inventory (FMCI). Fluid mechanics typically follows thermodynamics in the sequence of courses in thermal sciences, involves both the mechanics and dynamics of fluids, and builds on basic physics and Newtonian mechanics. This paper describes the process used for development of the FMCI, the details of how we determined the content, and examples of actual content of the instrument itself.

Index Terms - Concept inventories, Fluid Mechanics, Assessment

INTRODUCTION

Fluid mechanics is studied in many different disciplines. For example, in basic physics taught to freshmen and sophomores, a fluid is described, and pressure and density are defined. Hydrostatics is developed by taking into account the force on a static fluid element under the influence of gravity, followed by consideration of manometers and barometers. Fluid dynamics as introduced in basic physics includes conservation of momentum or the equation of continuity, Bernoulli's equation and ideas such as lift and thrust[1]. This is followed in many disciplines in engineering, and many of the natural sciences, with additional study of fluid mechanics.

Following the example of Hestenes and the Force Concept Inventory (FCI) [2], a cooperative effort of faculty at the University of Illinois, Champaign-Urbana and the University of Wisconsin-Madison has been aimed at development of a concept inventory in fluid mechanics. The Fluid Mechanics Concept Inventory or FMCI described here is aimed for use in assessment of Mechanical Engineering students who have or will be taking a course in fluid mechanics in Mechanical Engineering.

To begin the development, the first step was identification of the fluid mechanics concepts that were considered to be essential knowledge by Mechanical

Engineering students having completed an undergraduate fluid mechanics course in Mechanical Engineering. The identification of concepts was initially done by experienced faculty and completed prior to writing individual questions. Once the concepts were identified, then multiple questions were written for each of the concepts, allowing for validation [3].

Following the lead of Kraus and other work on the development of a heat transfer concept inventory, students have been utilized in the development of the FMCI [4-5]. They were used in the identification of concepts and misconceptions, in the evaluation and development of questions used on the FMCI, and in the answers to the questions, assisting in the identification of key false positive answers (typically resulting from common misconceptions.)

IDENTIFICATION OF CONCEPTS

Identification of key concepts in fluid mechanics was, and is, considerably more difficult than would have been required for the Force Concept Inventory (FCI). Fluid mechanics, like other engineering subjects, does not have the same kind of readily identifiable model as the FCI, and is a combination of a large number of somewhat disparate concepts.

The list of concepts developed by the faculty is shown in Table I. Concepts identified begin with the basic concepts used in fluid mechanics, such as fluid properties and identification of boundaries and boundary effects. Concept identification places dimensional analysis and similarity in basic concepts. Fundamental fluid relations include conservation of mass and momentum. Specific terms in the equations defining conservation of mass and momentum were identified. Finally, there is a list of special topics that could be included in a FMCI depending on the discipline where the FMCI was used.

As shown in Table I, there are 3 principal areas that together comprise approximately 25 different concepts. This means that a concept inventory that had multiple questions on each of the concepts would be at least 50 questions, although it might be preferable to have 75 questions. An inventory of 75 questions is likely too long, and so it is possible that for any given application of the FMCI, a reduced set of questions will need to be used, or the number of concepts assessed will need to be reconsidered.

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Concept Inventory Fluid Mechanics

Florian Genz



Concept Inventory Fluid Mechanics:

The Flight Physics Concept Inventory Florian Genz, 2025-07-18 The Flight Physics Concept Inventory FliP CoIn is the first research based conceptual assessment instrument for improving fluid dynamics learning and teaching This work gives insights into why and how the FliP CoIn was developed as well as how it is best used for improving conceptual learning Further this dissertation presents evidence for several dimensions of the FliP CoIn s validity and reliability Finally the author discusses key insights from the development process the data analysis and gives recommendations for future research As such this work is also written as a blueprint for future education researchers and instrument developers of other contexts The FliP CoIn s context areas are flow fluid dynamics and flight physics The FliP CoIn tests concepts of aerodynamic lift aerodynamic drag stall center of mass angle of attack and streamlines The latest version and translations are available for educators at physport.org or via flip.coin.uni-koeln.de

Teaching and Learning of Fluid Mechanics Ashwin Vaidya, 2020-12-02 This book contains research on the pedagogical aspects of fluid mechanics and includes case studies lesson plans articles on historical aspects of fluid mechanics and novel and interesting experiments and theoretical calculations that convey complex ideas in creative ways The current volume showcases the teaching practices of fluid dynamicists from different disciplines ranging from mathematics physics mechanical engineering and environmental engineering to chemical engineering The suitability of these articles ranges from early undergraduate to graduate level courses and can be read by faculty and students alike We hope this collection will encourage cross disciplinary pedagogical practices and give students a glimpse of the wide range of applications of fluid dynamics *Fox and McDonald's Introduction to Fluid Mechanics* Robert W. Fox, Alan T. McDonald, John W. Mitchell, 2020-06-30 Through ten editions Fox and McDonald s *Introduction to Fluid Mechanics* has helped students understand the physical concepts basic principles and analysis methods of fluid mechanics This market leading textbook provides a balanced systematic approach to mastering critical concepts with the proven Fox McDonald solution methodology In depth yet accessible chapters present governing equations clearly state assumptions and relate mathematical results to corresponding physical behavior Emphasis is placed on the use of control volumes to support a practical theoretically inclusive problem solving approach to the subject Each comprehensive chapter includes numerous easy to follow examples that illustrate good solution technique and explain challenging points A broad range of carefully selected topics describe how to apply the governing equations to various problems and explain physical concepts to enable students to model real world fluid flow situations Topics include flow measurement dimensional analysis and similitude flow in pipes ducts and open channels fluid machinery and more To enhance student learning the book incorporates numerous pedagogical features including chapter summaries and learning objectives end of chapter problems useful equations and design and open ended problems that encourage students to apply fluid mechanics principles to the design of devices and systems *The Scholarship of Teaching and Learning* Jacqueline

Dewar, Curtis Bennett, Matthew A. Fisher, 2018-04-26 *The Scholarship of Teaching and Learning A Guide for Scientists Engineers and Mathematicians* shows college and university faculty members how to draw on their disciplinary knowledge and teaching experience to investigate questions about student learning It takes readers all the way through the inquiry process beginning with framing a research question and selecting a research design moving on to gathering and analyzing evidence and finally to making the results public Numerous examples are provided at each stage many from published studies of teaching and learning in science engineering or mathematics At strategic points short sets of questions prompt readers to pause and reflect plan or act These questions are derived from the authors experience leading many workshops in the United States and Canada on how to do the scholarship of teaching and learning SoTL The taxonomy of SoTL questions What works What is What could be that emerged from the SoTL studies undertaken by scholars in the Carnegie Academic for the Scholarship of Teaching and Learning serves as a framework at many stages of the inquiry process The book addresses the issue of evaluating and valuing this work including implications for junior faculty who wish to engage in SoTL The authors explain why SoTL should be of interest to STEM science technology engineering and mathematics faculty at all types of higher education institutions including faculty members active in traditional STEM research They also give their perspective on the benefits of SoTL to faculty to their institutions to the academy and to students

Designing Better Engineering Education Through Assessment Joni Spurlin, Sarah A. Rajala, Jerome P. Lavelle, 2023-07-03 This book is written for engineering faculty and department chairs as a practical guide to improving the assessment processes for undergraduate and graduate engineering education in the service of improved student learning It is written by engineering faculty and assessment professionals who have many years of experience in assessment of engineering education and of working with engineering faculty The book reflects the emphasis placed on student outcomes assessment by ABET Inc the organization that accredits most U S engineering computer science and technology programs as well as providing substantial equivalency evaluations to international engineering programs The book begins with a brief overview of assessment theory and introduces readers to key assessment resources It illustrates through practical examples that reflect a wide range of engineering disciplines and practices at both large and small institutions and along the continuum of students experience from first year to capstone engineering courses through to the dissertation how to go about applying formative and summative assessment practices to improve student learning at the course and program levels For most institutions assessment of graduate education is new therefore there are readers who will be particularly interested in the chapters and examples related to graduate education This book concludes with a vision for the future of assessment for engineering education The authors cover five basic themes Use of assessment to improve student learning and educational programs at both undergraduate and graduate levels Understanding and applying ABET criteria to accomplish differing program and institutional missions Illustration of evaluation assessment activities that can assist faculty in improving undergraduate and

graduate courses and programs Description of tools and methods that have been demonstrated to improve the quality of degree programs and maintain accreditation Identification of methods for overcoming institutional barriers and challenges to implementing assessment initiatives

Engineering Education John Heywood, 2005-12-12 A synthesis of nearly 2 000 articles to help make engineers better educators While a significant body of knowledge has evolved in the field of engineering education over the years much of the published information has been restricted to scholarly journals and has not found a broad audience This publication rectifies that situation by reviewing the findings of nearly 2 000 scholarly articles to help engineers become better educators devise more effective curricula and be more effective leaders and advocates in curriculum and research development The author s first objective is to provide an illustrative review of research and development in engineering education since 1960 His second objective is with the examples given to encourage the practice of classroom assessment and research and his third objective is to promote the idea of curriculum leadership The publication is divided into four main parts Part I demonstrates how the underpinnings of education history philosophy psychology sociology determine the aims and objectives of the curriculum and the curriculum s internal structure which integrates assessment content teaching and learning Part II focuses on the curriculum itself considering such key issues as content organization trends and change A chapter on interdisciplinary and integrated study and a chapter on project and problem based models of curriculum are included Part III examines problem solving creativity and design Part IV delves into teaching assessment and evaluation beginning with a chapter on the lecture cooperative learning and teamwork The book ends with a brief insightful forecast of the future of engineering education Because this is a practical tool and reference for engineers each chapter is self contained and may be read independently of the others Unlike other works in engineering education which are generally intended for educational researchers this publication is written not only for researchers in the field of engineering education but also for all engineers who teach All readers acquire a host of practical skills and knowledge in the fields of learning philosophy sociology and history as they specifically apply to the process of engineering curriculum improvement and evaluation

Cambridge Handbook of Engineering Education Research Aditya Johri, Barbara M. Olds, 2014-02-10 The Cambridge Handbook of Engineering Education Research is the critical reference source for the growing field of engineering education research featuring the work of world luminaries writing to define and inform this emerging field The Handbook draws extensively on contemporary research in the learning sciences examining how technology affects learners and learning environments and the role of social context in learning Since a landmark issue of the Journal of Engineering Education 2005 in which senior scholars argued for a stronger theoretical and empirically driven agenda engineering education has quickly emerged as a research driven field increasing in both theoretical and empirical work drawing on many social science disciplines disciplinary engineering knowledge and computing The Handbook is based on the research agenda from a series of interdisciplinary colloquia funded by the US National Science Foundation and

published in the Journal of Engineering Education in October 2006 Qualitative Inquiry in Geoscience Education Research
 Anthony D. Feig, Alison Stokes, 2011 *Blended Learning in Practice* Amanda G. Madden, Lauren Margulieux, Robert S. Kadel, Ashok K. Goel, 2019-04-09 A guide to both theory and practice of blended learning offering rigorous research case studies and methods for the assessment of educational effectiveness Blended learning combines traditional in person learning with technology enabled education Its pedagogical aim is to merge the scale asynchrony and flexibility of online learning with the benefits of the traditional classroom content rich instruction and the development of learning relationships This book offers a guide to both theory and practice of blended learning offering rigorous research case studies and methods for the assessment of educational effectiveness The contributors to this volume adopt a range of approaches to blended learning and different models of implementation and offer guidelines for both researchers and instructors considering such issues as research design and data collection In these courses instructors addressed problems they had noted in traditional classrooms attempting to enhance student engagement include more active learning strategies approximate real world problem solving and reach non majors The volume offers a cross section of approaches from one institution Georgia Tech to provide both depth and breadth It examines the methodologies of implementation in a variety of courses ranging from a first year composition class that incorporated the video game Assassin s Creed II to a research methods class for psychology and computer science students Blended Learning will be an essential resource for educators researchers administrators and policy makers Contributors Joe Bankoff Paula Braun Mark Braunstein Marion L Brittain Timothy G Buchman Rebecca E Burnett Aldo A Ferri Bonnie Ferri Andy Frazee Mohammed M Ghassemi Ashok K Goel Alyson B Goodman Joyelle Harris Cheryl Hiddleston David Joyner Robert S Kadel Kenneth J Knoespele Joe Le Doux Amanda G Madden Lauren Margulieux Olga Menagarishvili Shamim Nemati Vjollca Sadiraj Donald Webster **Linear and Non-linear Mechanical Behavior of Solid Materials** Christian LExcellent, 2017-05-23 This book offers an essential introduction to the linear and non linear behavior of solid materials and to the concepts of deformation displacement and stress within the context of continuum mechanics and thermodynamics To illustrate the fundamental principles the book starts with an overview of solid mechanics experimental methods classes of material behaviors and the thermodynamic modeling framework It then explores linear elastic behavior thermoelasticity plasticity viscoplasticity fracture mechanics and damage behavior The last part of the book is devoted to conventional and magnetic shape memory alloys which may be used as actuators or sensors in adaptive structures Given its range of coverage the book will be especially valuable for students of engineering courses in Mechanics Further it includes a wealth of examples and exercises making it accessible to the widest possible audience *Special Papers* ,1934 *Tech Tally* National Research Council, National Academy of Engineering, Committee on Assessing Technological Literacy, 2006-07-27 In a broad sense technology is any modification of the natural world made to fulfill human needs or desires Although people tend to focus on the most recent technological inventions technology includes a myriad of devices

and systems that profoundly affect everyone in modern society Technology is pervasive an informed citizenship needs to know what technology is how it works how it is created how it shapes our society and how society influences technological development This understanding depends in large part on an individual level of technological literacy Tech Tally Approaches to Assessing Technological Literacy determines the most viable approaches to assessing technological literacy for students teachers and out of school adults The book examines opportunities and obstacles to developing scientifically valid and broadly applicable assessment instruments for technological literacy in the three target populations The book offers findings and 12 related recommendations that address five critical areas instrument development research on learning computer based assessment methods framework development and public perceptions of technology This book will be of special interest to individuals and groups promoting technological literacy in the United States education and government policy makers in federal and state agencies as well as the education research community *Conference Proceedings* ,2004 Journal of Engineering Education ,2005 Student Understanding of Pressurized Pipeline Concepts and the Application to Conceptual Change Theory Anne W. Baghdanov, Washington State University. Department of Civil and Environmental Engineering, 2013

Audience Response Systems in Higher Education: Applications and Cases Banks, David, 2006-02-28 This book discusses the importance of creating Audience Response Systems ARS to facilitate greater interaction with participants engaged in a variety of group activities particularly education Provided by publisher **Advanced Reactor Concepts (ARC)** Ali Zamani Paydar, Seyed Kamal Mousavi Balgehshiri, Bahman Zohuri, 2023-07-20 Nuclear engineers advancing the energy transition are understanding more about the next generation of nuclear plants however it is still difficult to access all the critical types concepts and applications in one location Advanced Reactor Concepts ARC A New Nuclear Power Plant Perspective Producing Energy gives engineers and nuclear engineering researchers the comprehensive tools to get up to date on the latest technology supporting generation IV nuclear plant systems After providing a brief history of this area alternative technology is discussed such as electromagnetic pumps heat pipes as control devices Nuclear Air Brayton Combined Cycles integration and instrumentation helping nuclear plants to provide dispatchable electricity to the grid and heat to industry Packed with examples of all the types benefits and challenges involved Advanced Reactor Concepts ARC delivers the go to reference that engineers need to advance safe nuclear energy as a low carbon option Describes theory and concepts on generation IV technology such as advanced reactor concepts ARC and electromagnetic pumps and compares different types and sizes Sets out the energy transition with critical carbon free technology that can supplement intermittent power sources such as wind and solar Explains alternative heat storage technology including Nuclear Air Brayton Combined Cycles Introduces advanced main instrumentation systems for in core probes *AAI-JE (ATC) Exam PDF eBook-Airports Authority Of India Junior Executive (Air Traffic Control) Exam PDF eBook* By Chandresh Agrawal Chandresh Agrawal, Nandini Books, 2025-04-22 SGN The AAI JE ATC Exam PDF eBook Airports Authority Of India Junior Executive Air Traffic Control

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Rau,2025-02-17 In the past ten years applications of generative artificial intelligence GAI have found rapidly growing use in medicine science and daily life Large language models LLMs opened up new avenues in particular for education LLMs have been used to create interactive educational content for students stimulate their curiosity generate code explanations and develop assessment questions Additionally LLMs been applied for language practice anxiety alleviation and feedback provision In higher education LLMs have shown potential for assisting in medical exam preparation and clinical decision making In school education LLMs can help teachers with automated evaluation of student responses and respective adaptive feedback More recently LLM based applications such as chatGPT have been used to generate teaching materials or assessment tasks across different subjects The fields understanding of the effects of the use of LLM based applications in classroom teaching however is still in its infancy GAI tools may help solving a range of tasks in education in particular with respect to teachers and students and teachers efforts to generate content However it is critical that teachers and students do not overly rely on GAI generated solutions but instead critically assess each solution Students should furthermore not use GAI tools to avoid investing relevant mental effort to create mental models or more broadly build up competencies

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