

# DEVELOPMENT OF A CONCEPT INVENTORY FOR FLUID MECHANICS

Jay Martin<sup>1</sup>, John Mitchell<sup>2</sup>, and Ty Newell<sup>3</sup>

**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

**Yan Bai**



## **Concept Inventory Fluid Mechanics:**

The Scholarship of Teaching and Learning Jacqueline M. Dewar, Curtis D. Bennett, Matthew A. Fisher, 2018 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      *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

Engineering Education John Heywood, 2006-01-24 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     *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     Qualitative Inquiry in Geoscience Education Research Anthony D. Feig,Alison Stokes,2011     *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     **Conference Proceedings** ,2004     **Special Papers** ,1934     **Journal of Engineering Education** ,2005     **American Journal of Physics** ,2002     *Use of Conceptual Pedagogy in an Introductory Physics Course* Howard Earl Brookshire,1998     Innovations in Engineering Education ,2004     General Catalog Iowa State University,1981     **A Study of Engineering Education at the Virginia Polytechnic Institute** Virginia Polytechnic Institute,1961     **Aerospace America** ,2003     Current Index to Journals in Education ,1996-04     *Index to NASA Tech Briefs* United States. National Aeronautics and Space Administration. Technology Utilization Division,1970     *CAETE.* ,2005     Which Degree Guide ,2001

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