Research-Integrated Curriculum in Geoenvironmental Engineering

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Introduction

Rapid growth in global population and industrial development in the past few decades have led to several environmental problems related to soil and groundwater. As public agencies, private firms, and academia embarked on projects aimed at seeking solutions to waste management and subsurface contamination problems, it became clear that the scientific and engineering issues involved were diverse and required adoption of interdisciplinary approaches. The need for interdisciplinarity in assessing and solving geoenvironmental problems requires that students, researchers, engineering personnel and research managers synthesize and apply principles from a diverse set of disciplines. The immense growth in research on waste containment and site remediation coupled with the need for interdisciplinarity, brings about the necessity for the development of multidisciplinary and integrated research and curriculum development programs in geoenvironmental engineering.

This paper presents a curriculum framework for geoenvironmental engineering developed with support from the National Science Foundation's Combined Research-Curriculum Development (CRCD) program. The objectives of this curriculum are:

1. To synthesize relevant principles and themes from a number of allied disciplines in sciences and engineering such as environmental engineering, geotechnical engineering/geology, water resources engineering/hydrology/hydraulics, chemical engineering, biological and agricultural engineering/biological sciences, and agronomy/soil sciences;
2. To incorporate rapidly evolving research on subsurface fate and transfer processes, site remediation and waste containment methods into the curriculum;
3. To provide exposure to a multi-agency perspective such that "real world" site remediation and waste containment problems could be solved within the constraints of state and federal regulatory agencies; and
4. To incorporate interactive and experiential learning-oriented education methods and interdisciplinary team experiences into design education.

From an academic perspective, fulfillment of these objectives requires that traditional "departmental" barriers are transcended and a topic-based program drawing from the expertise of numerous individuals from science and engineering programs is instituted. Figure 1 represents the required paradigm shift – from department-centered to topic/program-centered approach to research and education. Expertise from traditional departments must be pooled together to form coherent groups under four broad cluster areas of geoenvironmental engineering: i) site characterization, ii) site remediation, iii) contaminant fate and transport in geomedia, and iv) waste disposal.

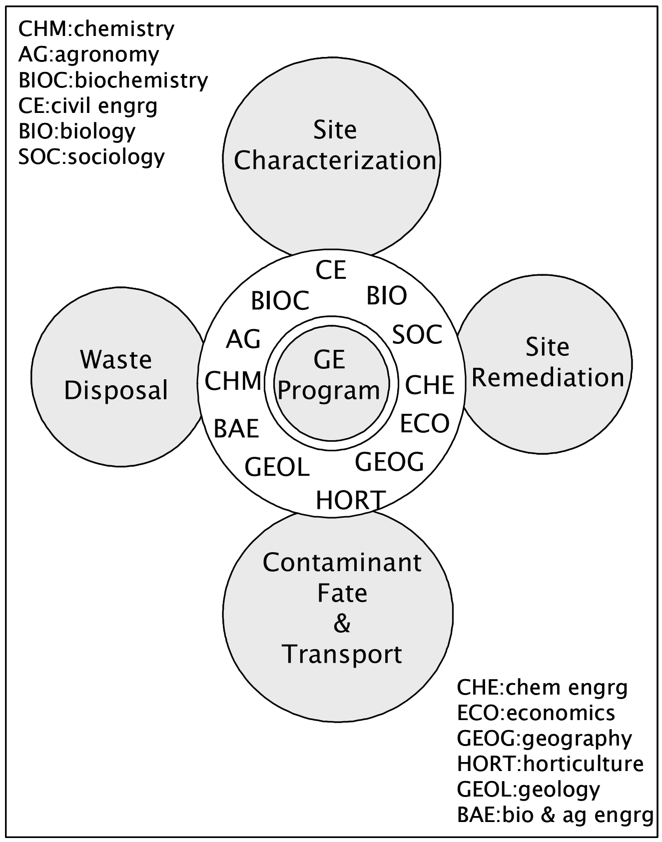

Figure 1. Topic/program-centered approach to geoenvironmental engineering (GE) research and education

What Constitutes Geoenvironmental Engineering?

Geoenvironmental engineering is defined in a broad sense as "*a field that encompasses the application of science and engineering principles to the analysis of the fate of contaminants on and in the ground; transfer of water, contaminant, and energy through geomedia; and design and implementation of schemes for treating, modifying, reusing, or containing wastes on and in the ground.*"[1] This definition encompasses the following specific themes:

1. Characterization of geomedia;
2. Modeling subsurface flow;

3. Analysis of contaminant generation, fate and migration through porous, fractured, and engineered media;
4. Design and analysis of physicochemical, thermal, and biological treatment of wastes and contaminated media to reduce or eliminate pollutants; and
5. Design and analysis of waste containment systems, such as landfills, slurry walls, grout curtains, dewatering systems, and deep disposal systems.

To elicit a diversity of opinions on what should constitute geoenvironmental engineering and to gather a consensus on the scope of the subject, a group of 20 experts from academia, industry, and state/federal regulatory agencies was invited to participate in an empowerment evaluation process[2]. The objectives of this task were: i) to identify the broad principles/concepts and applications with which a geoenvironmental engineer should be equipped, and ii) to identify constituents and stakeholders of geoenvironmental engineering.

The one-day long empowerment process led to a general consensus on the principles/concepts and applications that should constitute geoenvironmental engineering. Tables 1 and 2 show the top five categories in the order of decreasing percentage of participants' votes.

Table 1. Geoenvironmental Engineering Principles/Concepts by Rank Order.

	PRINCIPLES/CONCEPTS BY RANK ORDER	VOTES RECEIVED	PERCENT
1	Principles of fluid flow through geo-media – Surface and Groundwater Hydrology	17	18%
2	Mass transfer and mass transport processes	15	16%
3	Site characterization – solids, fluids, plumes, physicochemical and biological characteristics of media involved	11	12%
4	Soil Science – Biology, Physics, and Chemistry of Geomedia	10	11%
5	Remediation principles	8	8%

Table 2. Geoenvironmental Applications by Rank Order.

	APPLICATIONS BY RANK ORDER	VOTES RECEIVED	PERCENT
1	Physicochemical and biological remediation technologies - phytoremediation, pump-and-treat, air sparging, in-situ remediation, bioremediation/augmentation, passive remediation, reactive barriers, vitrification, etc.	17	20%
2	Waste containment and prevention of contamination – landfill/lagoon liners, well design, etc.	15	18%
3	Water resources, artificial recharge, salt water intrusion, well design	14	17%
4	Environmental monitoring	9	11%
5	Risk assessment	8	9%

The principles/concepts and applications identified in this empowerment process form a premise for designing a curriculum framework and graduate certificate program outlined in the following sections.

A Curriculum Framework for Geoenvironmental Engineering

The coherence of expert opinions on "what constitutes geoenvironmental engineering?" facilitated development of a curriculum framework for geoenvironmental engineering at Kansas State University. The curriculum was founded on a triad of courses targeted for delivery at the senior undergraduate level. These courses are: (1) Design of Groundwater Flow Systems, (2) Principles of Geoenvironmental Engineering, and (3) Geoenvironmental Engineering Design. A schematic of the 3-course series illustrating the role of supporting agencies and consultants is shown in Figure 2. The first two courses rely on university consortia experts for the incorporation of flow and transport models and infusion of state-of-the-art research into the curriculum, the third course draws heavily on the input from industry and regulatory agencies. The curriculum development is expected to lead to the establishment of a minor program for undergraduate students.

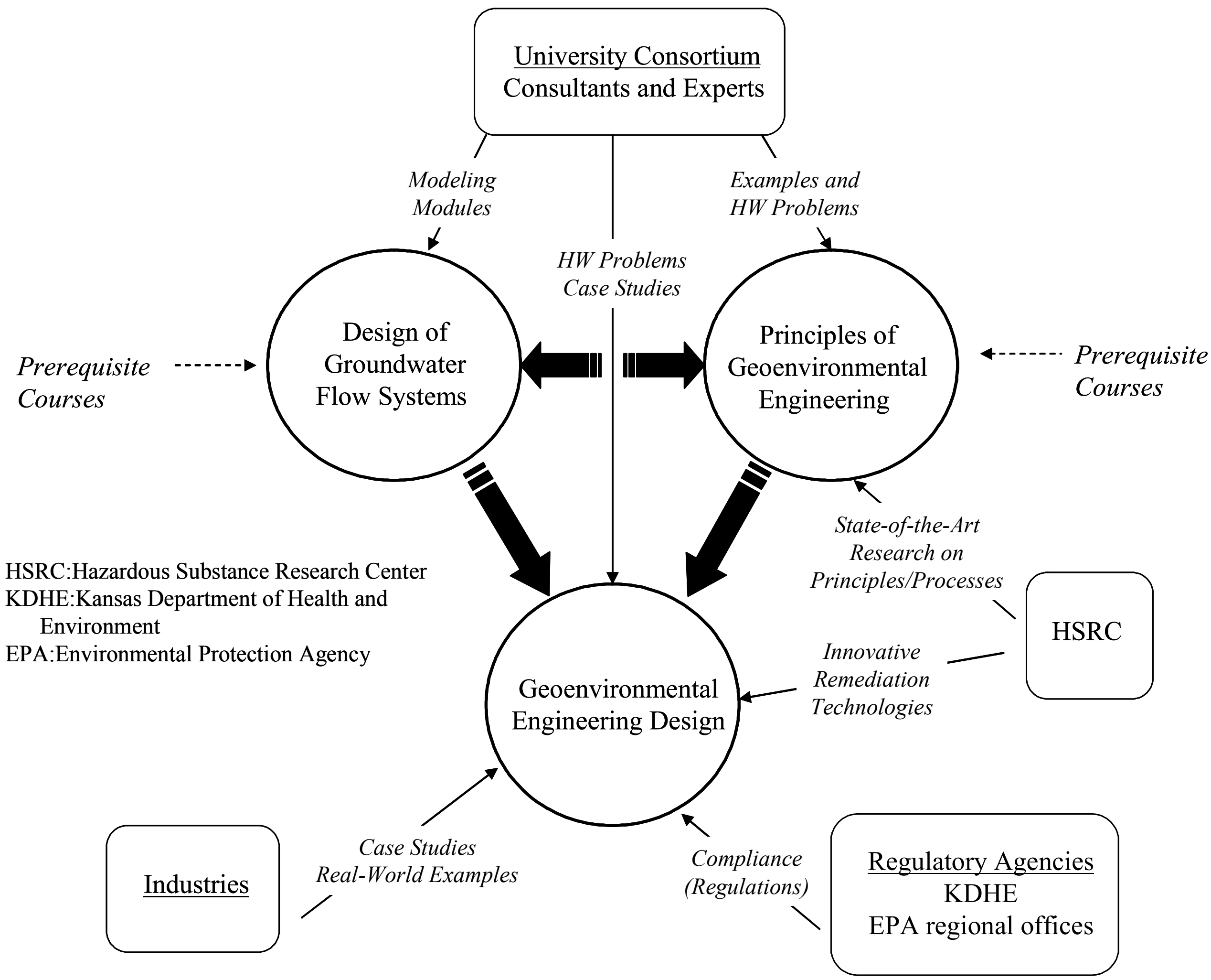

Figure 2. A schematic representation of KSU's geoenvironmental engineering curriculum.

Design of Groundwater Flow Systems is a 3 credit-hour course that introduces undergraduate students to the fundamental mathematical and physical concepts of groundwater flow. Students learn about field methods and simple analytic models and computer modeling tools useful in practical design. The major prerequisite for this class is fluid mechanics. Specific learning objectives of this and other courses in the geoenvironmental engineering curriculum are summarized in Table 3.

Table 3. Summary of the major learning objectives of the triad of courses constituting the geoenvironmental engineering curriculum.

COURSE	LEARNING OBJECTIVES
Design of Groundwater Flow Systems	(i) implementing a step-wise design approach to modeling groundwater flow for a problem of practical importance in the Kansas region; (ii) learning how to use modern groundwater computer tools based on GIS technology; (iii) assembling field data and using this data for model calibration and verification; (iv) exploring the socio-economic implications of proposed changes to groundwater management and policy; (v) contrasting computer simulations with simple calculations to decide when complexity must be incorporated into design; and (vi) developing a team report of high quality that can be placed within an on-line learning environment.
Principles of Geoenvironmental Engineering	(i) understanding the basic principles of soil fabric, soil structure and clay mineralogy; (ii) understanding flow and mass transport in soils; (iii) understanding basic principles of mass transfer; (iv) understanding basic methods of site characterization; (v) understanding sorption and phase equilibrium; (vi) understanding chemical and biological transformation processes
Geoenvironmental Engineering Design	(i) application of the principles of groundwater flow, contaminant transport, and the processes affecting environmental fate of contaminants in soil and groundwater systems to understand, evaluate, and design engineered geoenvironmental systems for the remediation of "real-world" contaminated sites; (ii) researching and using non-textual resources to solve problems; (iii) communicating progress and results in the form of written reports and oral presentations; and (iv) effective participation as a member of a multidisciplinary design team

Principles of Geoenvironmental Engineering is a 3 hour course that introduces students to concepts in soil formation, structure, and mass-transport and mass transfer in soils. This course also discusses approaches to waste containment and isolation, and the principles of physical, chemical and biological remediation processes. The prerequisites to this course include undergraduate coursework in soil science and groundwater hydrology.

Geoenvironmental Engineering Design is a 3 hour course that aims to provide students with a team design experience by working on a comprehensive project in geoenvironmental engineering. Interdisciplinary teams develop solutions to real-world problems through interactions with academic researchers, practitioners, and regulators. Design projects focus on resolving issues related to contamination of soil and groundwater. Prerequisites for this course include Design of Groundwater Flow and Principles of Geoenvironmental Engineering.

Graduate Certificate in Geoenvironmental Engineering

A Geoenvironmental Engineering Certificate program has also been developed at KSU to promote interdisciplinary education in geoenvironmental engineering. The educational objectives of the certificate program include (i) preparing graduates for careers related to geoenvironmental engineering; (ii) promoting interdisciplinary educational experiences in geoenvironmental engineering; and (iii) enhancing interactions among faculty and students in allied science and engineering disciplines related to geoenvironmental engineering. The certificate program will be administered and coordinated by the civil engineering department and the geoenvironmental engineering faculty will review the certificate program periodically. Faculty members with teaching and research interests in geoenvironmental engineering will be invited to join the geoenvironmental faculty.

Consistent with existing certificate programs at KSU, the Geoenvironmental Engineering Certificate requires 12 credit hours of coursework. This includes 9 hours from the triad of courses constituting the geoenvironmental engineering curriculum, and a 3 hour elective chosen from an approved list. At this time, approved elective courses include soil and environmental chemistry, physical properties of soils, soil physics, soil organic chemistry, advanced soil chemistry, advanced soil physics, non-point pollution engineering, designing with geosynthetics, seepage in permeable materials, water treatment processes, wastewater engineering, applied geostatistics, engineering properties of cohesive soils, environmental geotechnology, advanced soil mechanics, analysis of groundwater flow, environmental engineering chemistry, advanced topics in geotechnical engineering, advanced topics in environmental engineering, hazardous waste engineering seminar, surface phenomena, biochemical engineering, selected topics in biochemical engineering, advanced transport phenomena, hydrogeology, and advanced chemistry.

Assessment and Evaluation of Curriculum

Assessment of student learning in these courses will place emphasis on students' use of knowledge and complex reasoning processes rather than on their ability to recall declarative and procedural information. KSU's Office of Educational Innovation and Evaluation Assessment is consulted to develop student self-assessment instruments intended to ascertain the student's perception of the type and amount of learning in individual courses and in the 3-course sequence. Industry and academic consultants are intimately involved in evaluating student learning in the three courses. The evaluators will be asked to review student portfolios and indicate whether the criteria and standards of performance for each class met the expectations of practitioners and academics.

The evaluation process addresses four important questions using multiple sources of evidence: 1) Has important content been identified? 2) Have course materials and experiences been developed that adequately address that important content? 3) Are students learning what they need to learn? and 4) Are faculty who teach the courses using the evaluation information to make course improvements? Table 4 summarizes these sources of evidence and their frequency of collection.

Table 4. Evaluation & Assessment: Sources of Evidence and Frequency of Collection

QUESTIONS RELATED TO:	SOURCES OF EVIDENCE	FREQUENCY OF COLLECTION
Identification of course content	Best practices survey Industry needs assessment survey	One time, Fall 2003 One time, Fall 2003
Selection of course content and learning experiences	Expert review Student mid-semester and end of semester feedback Faculty feedback	Fall 2003 and Spring 2004 Every time course is taught Annual
Assessment of student learning	Student self-reflection Expert review	Every time course is taught 2003-2004 2004-2005
Effective Use of Technology	Web-based survey	Every time course is taught
Use of Information	Faculty survey Administrator survey	Annual End of grant period

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Bibliography

1. Reddi, L.N., and H.I. Inyang, *Geoenvironmental Engineering: Principles and Applications,* Marcel Dekker, Inc., New York, 2000.

2. Fetterman, D.M. *Foundations of Empowerment Evaluation*, Sage Publications, Thousand Oaks, California, 2001.