Project-Based Learning as a High-Impact Practice

Implementation, Impacts, and Implications

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Goals for this Talk

- Present a model for project-based learning
- Describe WPI’s project-based curriculum
- Explore evidence of its impacts
- Discuss implications for students, faculty, and institutions
What Constitutes Project Work?

• Authentic, open-ended problems
• Real, messy, interdisciplinary
• Goal, methods, criteria chosen by students
• Requires integration, analysis, synthesis
• Generation and communication of useful results
Objectives for Project-Based Learning

- Applying knowledge to complex problems in practical settings
- Understanding problems in social and cultural context
- Learning new topics quickly
- Communicating effectively in written, oral, and visual forms
- Interacting productively with teammates, faculty advisors, sponsors, communities
## Project Based Learning vs. Problem Based Learning

### Similarities

Both PBLs:
- Focus on an open-ended question or task
- Provide authentic applications of content and skills
- Build 21st century 4 C’s competencies
- Emphasize student independence and inquiry
- Are longer and more multifaceted than traditional lessons or assignments

### Differences

<table>
<thead>
<tr>
<th>Project Based Learning</th>
<th>Problem Based Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Often multi-disciplinary</td>
<td>More often single-subject</td>
</tr>
<tr>
<td>May be lengthy (weeks or months)</td>
<td>Tend to be shorter</td>
</tr>
<tr>
<td>Follows general, variously-named steps</td>
<td>Follows specific, traditionally prescribed steps</td>
</tr>
<tr>
<td>Includes the creation of a product or performance</td>
<td>The “product” may simply be a proposed solution, expressed in writing or in an oral presentation</td>
</tr>
<tr>
<td>Often involves real-world, fully authentic tasks and settings</td>
<td>More often uses case studies or fictitious scenarios as “ill-structured problems”</td>
</tr>
</tbody>
</table>

Source: J. Larner, Buck Institute, via *Edutopia*
The WPI Plan (1970)

- Project-Based Curriculum
  - Authentic problem solving
  - Emphasis on outcomes and abilities
  - Flexible requirements
  - Student responsibility for learning
  - Collaboration, not competition

- “Technological Humanism”
  - Addressing important needs
  - Considering impacts of technology
  - Understanding, working with others
  - Emphases beyond the major
Projects Across the Curriculum at WPI (2015)

- **1st year:** Great Problems Seminar
  - 6 credit hours, interdisciplinary

- **2nd year:** Humanities and Arts Capstone
  - Seminar or practicum in chosen area

- **2nd – 4th years:** Course Project Work
  - E.g., formative engineering design

- **3rd year:** Interactive Qualifying Project (IQP)
  - 9 credit hours, interdisciplinary gen ed

- **4th year:** Major Qualifying Project (MQP)
  - 9 credit hours, capstone in major field

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Great Problems Seminars

• Focus is on one global problem
  — Energy, food, water, health care, climate change

• Co-Instructors from different disciplines
  — Technical/Humanistic pairings

• Learning outcomes stress skill development rather than content knowledge

• This structure allows multi-faceted look at the problem
  — Economic, policy, technical, cultural

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Course Structure

• First Half
  – Many perspectives
  – Many assignments – individual and group
  – Lots of presentations and writing

• Second Half
  – Students divide into teams (3-5)
  – Select/Receive project topic – a small piece of the big problem
  – Research the problem, identify potential solutions, evaluate them, select one, develop an assessment plan
  – Produce a report/poster
Assessment

More than 50% of GPS alums said the GPS prepared them ‘much’ or ‘very much’ for the following activities:

- Functioning effectively on a team
- Solving complex real-world problems
- Assuming a leadership role on a team
- Interacting with faculty
- Developing a greater understanding of global issues
- Speaking clearly and effectively
- Using library research tools
- Thinking critically and analytically
- Drawing on information from multiple disciplines
- Understanding contemporary issues
- Being able to discuss and negotiate controversial issues
- Finding and critically evaluating information
Project Work in Math Courses

• Calculus Projects:
  – Assign homework out of the Physics or Chemistry Textbook... a “Study Abroad Experience”
  – Example: Where is the center of Massachusetts?

• Differential Equations Projects
  – Models from your major:
    ▪ Population models (everybody gets a piece of bread...)
    ▪ Heat-Loss models (drop the silly assumptions)
    ▪ Add time delay... and watch what happens.
Two Views, One Problem

- Compute the following:
  \[ \bar{x} = \frac{M_x}{M} = \frac{1}{2M} \int_a^b \rho \left[ (f(x))^2 - (g(x))^2 \right] dx \]

- Find the center of Massachusetts (Long Island)
- Is it near Rutland? (Farmingdale?)
Project Work in Chemistry

- Example: Pet Enzyme Project
  Student teams produce reports on an assigned enzyme, paralleling course content
  - Protein structure: online prediction and visualization tools
  - Catalytic mechanisms/kinetics: ditto
  - Metabolic pathways: enzyme regulation and research rationalization

- Brings the theoretical into the practical
- Links what can appear to be disparate concepts
- Utilizes tools available to professionals
- Makes things memorable!
## Assessment Results

<table>
<thead>
<tr>
<th>Area of Impact</th>
<th>Percentage Responding Positively (N=86)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Literature searching and search strategies</td>
<td>87</td>
</tr>
<tr>
<td>What biochemists do</td>
<td>79</td>
</tr>
<tr>
<td>Why we study the material in Biochem I</td>
<td>64</td>
</tr>
<tr>
<td>Working in groups</td>
<td>66</td>
</tr>
<tr>
<td>Scientific writing</td>
<td>53</td>
</tr>
<tr>
<td>Nothing</td>
<td>1</td>
</tr>
</tbody>
</table>
# Student Satisfaction

<table>
<thead>
<tr>
<th>Before and after introduction of project</th>
<th>%Agree:%Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-2</td>
<td>57:32</td>
</tr>
<tr>
<td>T-1</td>
<td>47:46</td>
</tr>
<tr>
<td>T=0</td>
<td>52:38</td>
</tr>
<tr>
<td>T+1</td>
<td>43:54</td>
</tr>
<tr>
<td>T+2</td>
<td>41:55</td>
</tr>
<tr>
<td>T+3</td>
<td>33:64</td>
</tr>
</tbody>
</table>
Projects in Engineering Design

• Team-taught, sophomore level
• Faculty “managers” offer design challenges posed by external clients
• 8-10 design teams of 3 students address each challenge
• Design teams mentored by undergrad “senior engineers”
• Course covers design process and principles
• Student teams do technical design on their own
• Weekly design reviews and reports
• Working prototype expected
Sample Results

- 18 designs, all responsive to user needs
- 100% course retention rate
- 76% of students reported over 20 hpw on task
- 93% agree “solidified understanding”
- 96% agreed “learned to apply previous knowledge”
- 20% volunteered to continue the work after the course

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Recommend and justify a material for the rod rigging of a racing yacht, to reduce its weight

- Fictitious client, realistic scenario
- Open-ended with multiple solutions: some constraints given, students must investigate others
- Deliverable: technical memo
- Detailed rubric to communicate expectations
- Students assigned to teams that work together throughout course: self and peer evaluation
- Formative feedback before submission: check-ins during class
Interactive Qualifying Project (IQP)

- Junior year, 9 CH, gen ed requirement
- Not a course – students conduct inquiry under faculty direction
- Teams of 3-4 from all fields
- Faculty from all fields
- Problem at society/technology interface
- Most sponsored by NGOs, gov’t, nonprofits
Educational Objectives of the IQP

- Research skills
- Problem solving
- Critical thinking
- Communication
- Teamwork & leadership
- Ethical awareness
- Contextual understanding of science & technology
  - Human needs and values
  - Social structures and policies
  - Cultural norms
Examples of IQPs

• Improving Community Nutrition
  – AIDS Project Worcester

• Promoting Sustainable Transportation
  – Facilities Department, WPI

• Alerting systems and egress for the deaf
  – VicDeaf, Melbourne, Australia

• Erosion and flood control in informal settlements
  – Namibia Housing Action Group
Major Qualifying Project (MQP)

- Senior year, 9 CH, in major
- Not a course
- Teams of 1-4, usually same major
- Advisor(s) from major
- Professional-level challenge, e.g., design or research
- Many sponsored by corporations, research labs (often for fee)
Educational Objectives of the MQP

- Application of knowledge and skills
- Research/design context
- Problem solving
- Critical thinking
- Communication
- Teamwork & leadership
- Preparation for workplace or graduate school
Examples of MQPs

- Water supply modeling for Wachusett Reservoir
  - MA Dept of Conservation & Recreation
- Cam blade load design
  - Gillette
- Sustainable landscape architecture
  - Stantec, Canada
- Human artery plaque progression
  - National Science Foundation
WPI Global Projects Program

• 65% of students complete at least one project in a fulltime immersion off campus

• About 50% do at least one project overseas

• WPI operates 40 off-campus Project Centers around the globe

• The typical cohort at a center is 24 students (6 teams of 4) and 2 resident faculty advisors
A Blend of Experiential Learning Models

- **Project-based learning**
  - Application of knowledge in authentic settings
  - Promotes problem solving, critical thinking

- **Study abroad**
  - Preparation for global engagement
  - Promotes cognition, personal development

- **Service learning**
  - Reflective interaction with communities
  - Promotes interpersonal skills, identity development

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Study Away (Sobania and Braskamp, 2009)

- Includes both study abroad and domestic off-campus experiences
- Can include elements of study abroad, project-based learning, and service learning
- Promotes many of the same learning outcomes
- Less costly than study abroad
- Fewer obstacles to faculty participation
- Easier to integrate into curricula
Off-Campus Operations

• Faculty Center Directors
  – Develop/maintain relationships
  – Identify projects
  – Recruit/select students

• Required Academic Preparation
  – Culture, language, context
  – Teamwork, writing, presentation
  – Goal, objectives, methods
  – Proposal to sponsor

• On-Site Immersion (7 weeks)
  – Faculty advisors on site
  – Fulltime project work
  – Close interaction with sponsors
  – Project report and presentation
Student and Program Evaluation

- Grades reflecting results and process
- Student ratings of learning and advising
- Sponsor feedback solicited
- Regular program assessment
  - Aligned with institutional LOs
  - Instrumental to accreditation
  - Used for improvement

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WPI Alumni Study

• Increasingly, other universities are moving toward project-based and experiential education

• WPI has 40 years of experience and 20,000+ Plan graduates to learn from

• Research questions:
  – *What are the long-term impacts of the IQP and MQP?*
  – *Do IQPs and MQPs prepare WPI alumni for success?*
  – *How do different groups experience the IQP and MQP?*
Study Overview

• **Alumni survey**
  – Professional, world view, and personal impacts
  – 25% response rate (n=2532)

• **Alumni interviews**
  – 25 in-depth interviews to explore “why”

• **Employer interviews**
  – Are WPI graduates different? How and why?
  – 10 in-depth interviews across sectors
Overview of Findings

• IQP and MQP convey *many* positive impacts
  – A wide range of professional abilities and skills
  – Broader world views and personal growth

• Some alumni groups report especially positive impacts
  – women
  – those who completed off-campus projects

• Alumni interviews reveal compelling stories of growth and transformation

• Employers see project work as a proxy for the skills and abilities they seek
Areas of Project Impact

• Professional abilities
  – Lifelong learning, ideation, problem solving
  – Ethical understanding, using current technology

• Interpersonal/communication skills
  – Teamwork, project management, leadership
  – Written and spoken communication, interpersonal dynamics

• Professional advancement
  – Succeeding in business or industry
  – Gaining knowledge to inform future plans

• World views
  – Awareness of global issues
  – Appreciating other people and cultures

• Personal growth
  – Development of a stronger personal character
  – Achieving work/life balance
Alumni Voices: Professional Preparation

“[Project work] is really a problem-solving and project management education, and that’s something I use constantly at work.”

“The [project], it’s close ... to what I do now. ... I can’t think of another school that would have been suitable for me to be doing what I do now ... life is projects.”

“I think the [projects] just really mimic, at a very early age—a formative age ... in your learning process— ... how to work, how to be successful.”
Alumni Voices: Personal Impacts

“[The projects]... give you the opportunity to become independent, work on your own, find ... solutions...it just gave me the opportunity to develop my character and drive.”

“To have something that really takes you out of your comfort zone ... where you can’t predict exactly what’s going to happen. ... helped me to become a stronger person as I headed out of college.”
Impact of Study Away

Alumni who “studied away” reported more positive impact in 33 of 39 areas

“I don’t think it really mattered where I went... my entire experience after the [project] was different than before... Somehow, something changed. I felt like a different person when I came back. ... I saw the reason why I went to college, because I saw something taken to completion in the real world.”

--Alumnus who did a domestic off-campus project
Benefits to Women

- Female alumni reported more positive impact in \textbf{36/39} areas
- 90\% of WPI students major in STEM fields, so this is of interest
- Research shows women are more motivated than men by context, application, and collaboration
Other Findings and Recurring Themes

• “Real world” aspect highly motivational
  — Authentic problems provide richness, complexity
  — Stakeholders provide motivation, context

• Adversity in projects viewed as an asset in hindsight

• Unpredictability of projects promoted learning, growth, and confidence

• Projects viewed as a “safe environment” to develop professional skills
Changing Faculty and Student Roles

- Faculty move away from
  - Dispensing information
  - Authority and expert
  and toward
  - Monitoring inquiry
  - Coach and facilitator

- Students move away from
  - Listening/watching
  - Dependence
  - *Gaining* knowledge
  and toward
  - Creating/discovering
  - Independence
  - *Making* knowledge

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How Are Project Students Evaluated?

- **Quality of results**
  - Careful research
  - Valid analysis
  - Persuasive writing
  - Effective solutions

- **Quality of process**
  - Steadiness of effort
  - Interactions with others
  - Written and verbal communication
  - Timeliness and professionalism
Faculty Roles in Project Advising

- Finding sponsors and projects
- Recruiting and preparing students
- Academic guidance
  - Discussing research plans
  - Meetings with team and sponsor
  - Responding to written drafts and presentations
  - Evaluating results and process
- Nonacademic roles
  - Logistical arrangements
  - Teamwork coaching
  - Maintaining relationships with sponsoring organizations

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Faculty Involvement

- All TT faculty (and many NTTs) advise projects as part of their teaching
  - Considered in T&P, annual reviews
  - “Apprenticeship” training
- Each year, >10% of faculty spend a term advising projects off-campus (from all depts.)
Institutional Impacts of PBL

- Student learning and culture
  - enhanced general education and major-specific outcomes
  - global preparedness
  - “make a difference”
- Faculty culture
  - broad involvement
  - pride in “signature program”
- Community and academic partners
  - mutual benefits
  - sustainable relationships
- Major focus for advancement
- Major focus for marketing
Other Benefits

- Rich accreditation evidence
  - “understand engineering in global/social context”
- Faculty professional/personal development
  - Powerful experience, attractive opportunity
- Multidisciplinary collaboration
  - Team teaching leads to other partnerships
- Faculty research opportunities
  - International partnerships

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Thank You
What Does It Cost, Who Pays?

- Students/families pay travel and living costs (up to $8K)
- Increasing number of global scholarships available
- Sponsor project fees cover about 20% of IGSD operating expenses and subsidize some student costs
- Faculty advisors are the greatest resource implication for WPI: time, travel, housing
- *Program cost/credit is similar to the overall curriculum*
On-Campus Project Scheduling

1 Term = 7 weeks
1 Semester = 2 Terms

3 Courses/Term
6 Courses/Semester

A Term
- Signal Analysis
- Psychology
- IQP

B Term
- Asian Studies
- IC Design
- IQP

C Term
- Probability
- History
- IQP

D Term
- Networks
- Materials
- VLSI Design

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Off-Campus Project Scheduling

1 Term = 7 weeks
1 Semester = 2 Terms

3 Courses/Term
6 Courses/Semester

A Term
Signal Analysis
Psychology
Probability

B Term
Asian Studies
IC Design
Project Preparation

C Term
IQP
In
Hong Kong

D Term
Networks
History
VLSI Design

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### Interdisciplinary (IQP) Centers

- Tirana, Albania
- Melbourne, Australia
- Hangzhou, China
- Hong Kong, China
- San Jose, Costa Rica
- Copenhagen, Denmark
- Thessaloniki, Greece
- Mandi, India
- Venice, Italy
- Ifrane, Morocco
- Windhoek, Namibia
- Wellington, New Zealand
- Asuncion, Paraguay
- Panama City, Panama
- Moscow, Russia
- Cape Town, South Africa
- Zurich, Switzerland
- Bangkok, Thailand
- London, UK
- Washington, DC
- Boston, MA*
- Nantucket, MA
- Springfield, MA*
- Worcester, MA*
- Bar Harbor, ME
- San Juan, PR

*Indicates additional locations for specific programs or events.*
Other Centers

Major (MQP) Centers
- Nancy, France
- Wuhan/Beijing, China
- Shanghai, China
- London/Glasgow, UK
- Kyoto, Japan
- Budapest, Hungary
- Nova Gorica, Slovenia
- Silicon Valley, CA
- MIT Lincoln Laboratories, MA
- Wall Street, NY

Humanities Centers
- Ifrane, Morocco
- London, UK
- Buenos Aires, Argentina
- Konstanz, Germany
Support and Scaffolding

- Nonacademic preparation
  - Mandatory orientations, policies
  - Health, safety, sexual assault
- On-site advisor training
  - Managing risk, dealing with crises
  - Handling teamwork & personal problems
  - Building relationships with sponsors
  - Representing WPI locally
- Range of support offices
  - Interdisciplinary and Global Studies
  - Gordon Library
  - Student Development & Counseling
  - Office of Student Life
  - Accounting, financial aid, etc.
<table>
<thead>
<tr>
<th>Professional Impacts</th>
<th>% Positive Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility for own learning</td>
<td>89</td>
</tr>
<tr>
<td>Develop ideas</td>
<td>89</td>
</tr>
<tr>
<td>Solve problems</td>
<td>88</td>
</tr>
<tr>
<td>Effective professional interactions</td>
<td>87</td>
</tr>
<tr>
<td>Function effectively on a team</td>
<td>86</td>
</tr>
<tr>
<td>Effectively manage a project</td>
<td>86</td>
</tr>
<tr>
<td>Write clearly and effectively</td>
<td>83</td>
</tr>
<tr>
<td>Succeed in business or industry</td>
<td>78</td>
</tr>
<tr>
<td>Be an effective leader</td>
<td>78</td>
</tr>
<tr>
<td>Speak clearly and effectively</td>
<td>76</td>
</tr>
<tr>
<td>Personal Impacts</td>
<td>% Positive Responses</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Stronger personal character</td>
<td>87</td>
</tr>
<tr>
<td>Feeling own ideas are important</td>
<td>79</td>
</tr>
<tr>
<td>Feeling able to make a difference</td>
<td>66</td>
</tr>
<tr>
<td>Enriched personal life</td>
<td>64</td>
</tr>
<tr>
<td>Feeling connected to WPI</td>
<td>62</td>
</tr>
<tr>
<td>Achieving work/life balance</td>
<td>53</td>
</tr>
<tr>
<td>Personal Impacts</td>
<td>% Positive Responses</td>
</tr>
<tr>
<td>------------------------------------------------------</td>
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</tr>
</tbody>
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“...taking pride in your work, operating according to a strong work ethic, persevering through adversity, being self-motivated, feeling self-confident, feeling self-aware, and operating according to a well-defined code of personal values”
## Impact of Projects on World Views

<table>
<thead>
<tr>
<th>Area of Project Impact</th>
<th>%“Much” or “Very Much”</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On campus</td>
</tr>
<tr>
<td>Ability to view issues from different perspectives</td>
<td>52</td>
</tr>
<tr>
<td>Understanding people of other cultures</td>
<td>19</td>
</tr>
<tr>
<td>Understanding global issues</td>
<td>24</td>
</tr>
<tr>
<td>Respect for other cultures</td>
<td>17</td>
</tr>
</tbody>
</table>
## Personal Impacts of Projects

<table>
<thead>
<tr>
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<th>% “Much” or “Very Much”</th>
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<tbody>
<tr>
<td></td>
<td>On campus</td>
</tr>
<tr>
<td>Development of a stronger personal character</td>
<td>64</td>
</tr>
<tr>
<td>Enriched life in non-academic or work-related ways</td>
<td>28</td>
</tr>
<tr>
<td>Feeling able to &quot;make a difference&quot;</td>
<td>38</td>
</tr>
<tr>
<td>Ability to achieve work/life balance</td>
<td>27</td>
</tr>
<tr>
<td>Feeling connected to the WPI community</td>
<td>17</td>
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</tbody>
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### Impact of Projects on Professional Skills

<table>
<thead>
<tr>
<th>Area of Impact</th>
<th>*** % “Much” or “Very Much” ***</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On campus</td>
</tr>
<tr>
<td>Ability to function effectively on a team</td>
<td>65</td>
</tr>
<tr>
<td>Ability to effectively manage a project</td>
<td>65</td>
</tr>
<tr>
<td>Interact in a professional capacity</td>
<td>58</td>
</tr>
<tr>
<td>Ability to write clearly and effectively</td>
<td>53</td>
</tr>
<tr>
<td>Ability to be an effective leader</td>
<td>52</td>
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<tr>
<td>Understanding ethical responsibilities</td>
<td>30</td>
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</table>