



Engagement in Practice: Learning Applications of MSE for Design of Community Based Shelter for Housing Insecurity

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Dr. Kevin M Fitzpatrick, University of Arkansas

Kevin M. Fitzpatrick, PhD, is a community sociologist with 35 years of experience as a researcher, consultant, and advocate. Kevin is a University Professor in the Department of Sociology and Criminology at the University of Arkansas. Since 2005, he has devoted the majority of his work-focus on helping communities throughout Arkansas better understand the challenges they face, and the types of strategies they might consider adopting to address those challenges. He has published 5 books and more than 75 peer-reviewed articles and book chapters that have continually emphasized the theme that place matters. Dr. Fitzpatrick is currently working with a multi-disciplinary team to develop technological innovations to address place-based food insecurity.

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Dr. Salil Bapat is currently a Post-doctoral Research Associate in the Department of Mechanical Engineering at the Purdue University under the mentoring of Prof. Ajay P. Malshe since March 2020. Dr. Bapat holds a Ph.D. degree in Microelectronics-photonics from University of Arkansas with emphasis on 'tribology and surface characterization'. He has master's and bachelor's degree in Materials Science and engineering with experience in semiconductors, thin films processing and materials characterization. He has been involved with Prof. Malshe in teaching the introduction to materials class at the University of Arkansas for last 5 years in the capacity of teaching assistant, co-instructor and instructor.

Community Engagement in Practice: Learning Applications of MSEM in Developing Alternative Housing Designs for Addressing Homelessness

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Abstract

Homelessness/ housing insecurity is a growing challenge across the US and the world. Students, especially Gen-Z, are about to enter the workforce where insecurities including housing insecurity are common observations in daily life. Generating engineering student's awareness of housing insecurity was the key objective of the presented work as a part of Introduction to Materials Science and Engineering, and manufacturing (MSEM) class in the mechanical and industrial engineering curriculum. A team of a social scientist, mechanical and manufacturing engineer and materials engineer teamed in the summer of 2018 to design a project where a class of 83 students would undertake a project in the Fall 2018 semester. The goal of the project was to apply the understanding of the material's structure-property-applications relationships to identify specific materials for meeting engineering specifications for various components of community housing in Northwest Arkansas (NWA). The housing designs were produced by architects in close collaboration with a social scientist. Examples of various housing design components included material recommendations for kitchen tents, bathroom shower flooring, outdoor community decks, common area kitchen tops, and others. Each design component was delegated to 3 groups with 3 students per group to recommend materials for very high durability, simplicity of installation and low price for frugal engineering. Through this process, students: 1) developed an understanding of a growing major societal problem in America as they were asked to visit and get familiarized with the problem; and 2) studied the architectural components for developing application-specific material/product recommendations using the structure of a material, desired properties, commercial availability, pricing and recommended vendors. This was approximately an 8-week long exercise whereby students submitted their recommendations in a team report, later submitted to the team of the social scientist and the architect. This paper would detail the results of this phase-I project and the implantation model.

Introduction:

Over the last two decades, materials science and engineering, and manufacturing (MSEM) has evolved into an important, interdisciplinary subject area in the engineering curriculum [1]–[3]. As a result, introductory undergraduate level MSEM class (with or without lab component) has become part of traditional non-MSEM engineering programs such as mechanical and industrial engineering. In some cases, this type of class is a required component of an undergraduate course curriculum. Covering the depth and breadth of an interdisciplinary and

hands-on subject like MSEM in a single semester presents a significant challenge in terms of engaging non-MSEM students throughout the semester. The authors have previously reported successful implementation of a pedagogical approach involving a project component [4] where the students picked the material for research-based learning based on their hobbies or personal interests. The motivation behind this approach was to encourage and engage students in curiosity-driven project-based learning within the framework of concepts discussed in the class. To advance the approach further, a central theme, focusing on a critical social problem, was implemented as a strategy for creating more social awareness, clarity, uniformity, and potential outreach impact to class assignments.

The objective of this project was to understand the utilization of structure-property-material manufacturing process-application of the materials and its implementation for a specific community-based project in NWA, aimed at working on alternative housing designs to address sheltering needs of a chronic homeless population. This process required students to understand the 'structure-property-processing-performance' and apply the learning for a specific engineering application/component within the constraints of design, function and cost and manufacturing. At the same time, students were introduced to the topic of housing and homelessness by our community partners to help them better understand the specific needs and importance of developing housing alternatives to this special needs population.

The motivation of this project is the converging application of fundamental engineering learning for social engineering. As both visible and invisible homeless sub-populations continue to grow in the United States in the midst of a growing housing crisis related to both access and affordability, alternative strategies for housing and materials design are critical. Social scientists and community partners continue to look for alternatives to traditional housing and are actively finding ways to address these complicated needs. The piloted class, where the students are learning structure, resultant properties of materials and processes for a diverse set of applications, adopted a specific social problem to identify and work on strategies using a theoretical and practice-based engineering solution. At the same time, students were exposed to lectures and extensive resources to help them better understand the population, the problem, and the challenges related to finding secure and safe housing for chronic homeless persons.

As a result of this semester-long process, this pilot project brought together sociology, a local homeless service provider, community design center, mechanical engineering professor, and MSEM students to 1) coalesce around a common theme and work together in teams to apply their classroom learning to identify specific materials for various parts of alternative housing designs for engineering specifications, and 2) develop classroom materials to help students better understand the manufacturing and commercial feasibility of the proposed materials as well as the practical application of and utility in those proposals for usage in housing construction.

Syllabus and Scope of the class:

In the scope of the MSEM class [5], students studied the physical and chemical properties of materials using an application-driven approach. The materials of interest were: metals, polymers, ceramics, and composites. Students learned the interactive relationship between structure, properties, and processing of materials emphasized for various engineering applications. Along

with this textbook, students had access to the materials design and selection software [6]. Following were the key topics for the class:

1) Introduction to different types of materials for conventional and modern industrial product applications with an emphasis on "application-specific materials' selection for engineered part(s) or system(s)"; 2) Study application intended interactive relationship between material structure, properties, behavior, and processing of materials; 3) Introduction to metals, polymers, ceramics, (and composites); and 4) Introduction to techniques for materials processing and testing. Overall the final project report was weighed for 10% of the final total grade.

Project details and execution:

The project was implemented over a 6-week long period where students developed their solution in parallel with the classroom discussion on materials properties, materials selection, and materials processing. During the middle of the semester, students were provided with clear instructions and expectations about the project through classroom discussions and the homework assignment dedicated to the project. Also, students received an entire class period of lecture and discussion around the topics of housing and homelessness. More importantly, our partner in sociology had extensive experience in working with local non-profits throughout the region and is currently leading a design and implementation team to build temporary housing for the chronic homeless population in the region. The class was divided into groups (an average of three students per group) to execute the project. Each group was assigned a specific component of the alternative housing design as their component/material for research. These components included:

1) glass panels for windows and walls; 2) indoor flooring; 3) kitchen/ warming tent; 4) outdoor flooring with no shades; 5) interior bathroom shower floors; 6) outdoor flooring under shade; 7) all-weather fabric roof covering; and 8) outdoor walkways.

After the formation of the teams, a homework assignment was developed and distributed to the class. The purpose of this assignment was to get students to familiarize themselves with the problem, study the application-specific design component assigned to them as a team, and build a framework for their final project report. The assignment was divided into the following four sections listed below with their intended purpose:

As a form of constructive feedback, the homework assignments were graded for their readiness to be implemented as a class project. The purpose of this feedback was to ensure that the corrective actions (if required) regarding the choice of materials, details of the design/property requirements and overall depth of the project were communicated to the groups well in advance to the final submission deadline. Throughout the remainder of the semester, the instructor and the teaching team were accessible during the drill, office hours and by appointment for discussion and providing guidance.

Students were asked to submit their final report in the form of a ring-bound hard copy along with a soft copy of the PowerPoint slides. As per the project rubric, the report was comprised of the following outlined sections covering various aspects of materials science and engineering and its application to the proposed solution addressing the social problem:

1) Currently selected component application; 2) Material part specifications; 3) Desired Material Properties & Functionalities; 4) Structures; 5) Design considerations, 6) Manufacturing

process sequence; 7) Manufacturers and pricing; 8) New suggested applications (at least two); 9) Material Properties & Application Design considerations; and 10) References.

Outcomes and conclusion:

The report submissions were graded based on their depth, detailed discussion, and recommendations that made the practical connection between classroom learning and the need for alternative housing designs. The reports were graded by the instructor and the director of the community engagement segment of the program. An example of a report that received the highest grade is shown in Figure 1 below. For each component application, the top-graded report(s) were selected and delivered for sharing with the design architects who were responsible for proposing a range of options to the construction team as they prepared drawings and construction estimates. Overall, the recommendations received positive feedback from the design architects and the community engagement team. Several conversations took place between the community partners, architects, and the social science team member. All reports indicated that the proposals that were generated by this highly engaged class had generated an important set of design and build considerations.

To summarize, as a class, the “adopt-a-material for alternative housing strategies for homeless populations” project was successfully implemented where students studied and recommended specific engineered material for various components of a chronic homeless program and shelter that specifically was designed by the architects to address the complicated and varied needs of the homeless population in the local community. Students recommended these materials using knowledge regarding their intended applications (e.g. a canvas tent for the common kitchen area, an outdoor walkway in the shade, multi-purpose flooring, bathroom fixtures, etc.), desired functional demands on the application and desired properties along with material’s structure. Finally, students included in the report how these solutions would be manufactured and where and for how these material solutions could be purchased. We believe that this piloted class provided an excellent hands-on experience for students to apply classroom learning to a critical social problem in the form of social innovation.

Acknowledgments:

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References:

- [1] W. J. Askeland, D. R., & Wright, “Introduction to Materials Science and Engineering,” in *Essentials of Materials Science & Engineering*, SI Edition., Cengage Learning, 2013, pp. 1–18.
- [2] J. P. Mercier, G. Zambelli, and W. Kurz, “Materials,” in *Introduction to Materials Science*, Elsevier, 2002, pp. 1–16.
- [3] W. D. Callister and D. G. Rethwisch, “Introduction,” in *Fundamentals of Materials Science and Engineering: An Integrated Approach*, 5th ed., Wiley, 2016.
- [4] “Adopt-a-Material”: A Case Study for Self-driven Learning Process for Undergraduate Students Paper presented at 2019 ASEE Annual Conference & Exposition, Tampa, Florida.

[5] D. R. Askeland and W. J. Wright, *The Science and Engineering of Materials*. Cengage Learning, 2016.

[6] <https://grantdesign.com/education/ces-edupack/>

Sheet Vinyl for Bathroom Flooring

Shelter for Homeless



1

II. Material part specifications (5 marks):

Material: PVC (flexible, Shore A85)

- CAS #: 9002-86-2 (PVC)
- Composition: PVC compound (CH_2CHCl)_n and plasticizer (20-30%)

Material Properties: [6]

Density	1330 - 1440	kg/m ³
Young's Modulus (at 85°C)	0.03 - 0.035	GPa
Hardness (Shore A)	85	
Impact Strength (23 °C)	600	kJ/m ²
Electrical Resistivity	3.18e18	μohm-cm
Water absorption	0.3 - 0.35	%
Durability (water, fresh)	Excellent	

References: [3], [5], [6]

4

Project Overview Quad Chart (5 marks)

I. Current selected component application: Interior for bathroom shower floor	Title: Sheet Vinyl for Bathroom Flooring Student Names: Jared Gilliam, Collin Thompson, Justin Stump
II. Material part specifications: Material Properties and Safety Sheets for PVC	Material: Sheet Vinyl Application: Interior for bathroom shower floor
III. Desired Material Properties & Functionalities: Slip resistant, corrosion resistant, growth prevention, low maintenance, water resistant, electrically insulating	VIII. New suggested applications: Heated blankets and clear tubing
IV. Structure: Polyvinyl chloride composite, amorphous structure	IX. Material Properties & Application Design considerations: Flexibility with corrosion resistance, high tensile strength, lightweight, thermally conductive, low cost
V. Design considerations: Appropriate thickness, properly laid with adequate drainage	
VI. Manufacturing process sequence: Mixture of powder and liquid chemical components rolled and oven heated to achieve texture and color	
VII. Manufacturers: Armstrong Flooring, Mannington Flooring	

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III. Desired Material Properties & Functionalities (5 marks):

Application Criteria

- Environment:**
 - High humidity and moisture
 - High use and wear
 - Elevated from ground
 - Likely not well thermally insulated
- Situation**
 - Low budget
 - Bathroom layout
 - Roughly 200 square feet of flooring

Desired Properties


- Water resistance
 - Low permeability
- Slip resistance
 - High coefficient of friction
- Low maintenance
 - Corrosion resistance
 - High durability
- Electrically insulating
- Non-toxic

5

I. Current selected component application:

Component: "Interior for bathroom shower floor"

- Bathroom trailer roughly 10" by 20"
- Two different types of use:
 - Bathroom floor
 - Shower floor
- For transitional homeless shelter
 - High use and wear
 - Low budget
 - Must be accessible to elderly and disabled

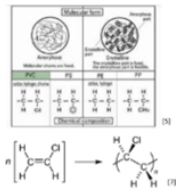


Reference: [3] (Image)

3

IV. Structures (5 marks):

- Vinyl flooring made from polyvinyl chloride (CH_2CHCl)_n, plasticizers (typically phthalates), and other additives
- The dense, amorphous structure of PVC gives it low permeability and water resistant properties
- Presence of chlorine adds chemical stability, making it fire retardant and resistant to oxidation and acids
- Plasticizers add flexibility [6]




References: [6], [6], [7]

6

Figure 1: Sample project report

V. Design considerations (5 marks):

- Flooring should be appropriate thickness for bathroom
- Flooring must be properly installed for specific bathroom layout, with holes for drainage
- Sheet vinyl is preferred, as plank or tile vinyl would have seams that water could seep through, damaging the floor



Example of how vinyl flooring would be implemented [9]

References [8]

7

VIII. New suggested applications (at least two; 5 marks):

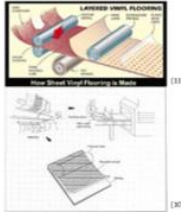
- Vinyl can be used in heated blankets because of
 - Water resistance
 - Durability
 - Flexibility
 - Thermal conductivity
- Vinyl can also be used for clear tubing because of
 - Lightweight
 - Ability to handle a wide variety of chemicals, gases, and liquids
 - Made from non-toxic ingredients

References [14], [15], [16]

10

VI. Manufacturing process sequence (5 marks):

- Step 1: In two separate vats, powder ingredients (PVC resins, pigments, and calcium carbonate) and liquid ingredients (plasticizers, fungicides, UV stabilizer, and blowing agents) are mixed before being combined and filtered.
- Step 2: Mixture is applied to wood pulp or paper backing and vinyl foam is fused to backing through heating at 220°C.
- Step 3: Designs are applied by rollers and dried in between applications before wear layer is applied (PVC resin and plasticizers).
- Step 4: Baked in oven at 220°C activating blowing agent and chemical embossing which gives texture through chemical inhibitors contained in different inks.
- Step 5: Further mechanical embossing can be done by engraved rollers before sheets are roller and shipped.

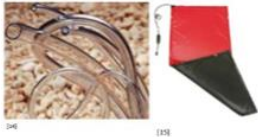


References [9], [10], [11]

8

IX. Material Properties & Application Design considerations (10 marks):

- Price: \$2.64-3.04 per kg
- Tear Strength: 76-80 N/mm
- Thermal Conductivity: 0.16-0.2 W/m°C
- Fracture Toughness: 1.49-1.54 MPa·m^{0.5}
- Tensile Strength: 19-20 MPa
- Flexural Modulus: 0.03-0.035 GPa
- Flexural Strength: 20-21 MPa
- Recyclable
- Excellent in fresh and saltwater



References [4], [14], [15]

11

VII. Manufacturers and pricing (at least 2; 5 marks):

Manufacturers and Sellers:

- Armstrong Flooring
- Mannington Flooring
- Both source to sellers around NWA:
 - Kings Floor Covering (Fayetteville)
 - Tom January Floors Inc. (Fayetteville)
 - Redmon Flooring (Springdale)
 - Carpet Center (Springdale)
 - Flooring America by Carpet Smart (Bethel Heights)

Pricing:

- Varies based on the seller
- Typical resilient vinyl can range from \$1.00-\$2.00 per square foot
- Luxury vinyl can be closer to \$4.00-\$5.00 per square foot



References [12], [13]

9

References

[1] "Engineering Presentation," University of Arkansas Community Design Center

[2] "PVC Safety Data Sheet," Sigma-Aldrich

[3] "Vinyl Flooring," The Vinyl Institute

[4] "Vinyl Flooring," The Vinyl Institute

[5] "Vinyl Flooring," The Vinyl Institute

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[13] "Vinyl Flooring," The Vinyl Institute

[14] "Vinyl Flooring," The Vinyl Institute

[15] "Vinyl Flooring," The Vinyl Institute

[16] "Vinyl Flooring," The Vinyl Institute

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Figure 1(continued): Sample project report