Enhancing Instruction by Uncovering Instructor Blind Spots from Muddiest Point Reflections in Introductory Materials Classes

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This paper discusses how Instructor Blind Spots (IBS) revealed from student muddiest point reflections can be used to enhance the effectiveness of course content, classroom delivery and student achievement. Instructor Blind Spots (IBS) could be broadly defined as faulty assumptions made by a class instructor about students' prior knowledge of their vocabulary, problem solving skills, conceptual knowledge, and other facets of conceptual knowledge. The IBS can be elicited by formative feedback from various sources, such as end-of-class muddiest points, classroom activities, and classroom discussions and questions. Such IBS may impede learning because students have difficulty with undefined or misdefined terms, lack of necessary skills, or misconceptions and other issues. After IBS are uncovered and diagnosed, they can inform the instructor of the aforementioned issues, then she or he can compensate and correct their IBS in a current class and, with that awareness, change instructional strategies and content to avoid them in future classes. This can result in more positive class learning outcomes.

In introductory materials classes, formative feedback from students through muddiest points and other mechanisms can reveal students' learning issues such as misdefined vocabulary, knowledge gaps, difficult concepts, and misconceptions. The source of such issues can arise from the students themselves, but some of these issues, can sometimes also arise from instructors. If so, they have an opportunity to reveal and identify IBS which they did not recognize or overlook because they may not have known about what students do not know. A few examples include the following. When materials instructors cover polymer structure, they discuss weak van der Waals bonding between long chain molecules, but students may only have heard in chemistry about the similar phenomenon of London dispersion forces between molecules, causing student confusion and concern until the issue is addressed. Another issue when initially discussing bonding, in particular metals, some students identify bonding in a metal as ionic because metallic bonding may not have been discussed in chemistry, which can be readily addressed. In considering solutions, the majority of the students in the author's classes believe that supersaturation of a liquid means that there is an excess amount of a second phase of solute that has come out of a saturated solvent, when in reality there is an excess of a solute in a solvent beyond equilibrium that gives a supersaturated solution. This misconception can make the teaching of precipitation hardening difficult until corrected. These and other IBS will be presented and discussed in the paper, as well as approaches to addressing these IBS, and associated impact on learning outcomes. Such approaches can include altering teaching strategies, modifying content, giving instructor feedback on muddiest points, and creating class activities that address IBS. Uncovering and addressing such IBS makes teaching both more challenging and rewarding with the opportunity of improving the classroom experience for both students and instructors.

Introduction

Research has shown that the combination of active learning through student engagement combined with frequent formative feedback is more effective than traditional knowledge transmission by lecture for achieving improved student attitude, persistence, and achievement (1-5). In student-centered learning, students engage with one another in relevant activities that promote conceptual development by defining and using vocabulary, discussing and debating concepts, and practicing skills that are required in using problem solving strategies. They draw on prior knowledge and integrate it with new knowledge within their conceptual framework, and then building their knowledge through questioning and/or supporting one another. In a large scale analysis of many studies, Freeman et. al. (1) showed that student centered learning resulted in higher achievement and comprehension on concept inventories and that students were less likely to fail than in similar classes with instructor-centered teaching. Another key component in evidence-based teaching is two-way formative feedback where student understanding is solicited by techniques such as in-class questions or end-of-class minute papers or "muddiest points" where students briefly describe their learning issues from that day's class (6). This promotes metacognition, the reflection of their own learning with regard to class content, and also reinforces their conceptual framework on a given topic (4). The instructor then reviews the students' learning issues from this formative feedback. Research has shown that addressing learning issues as quickly as possible with immediate feedback is very effective for improving motivation and learning (5). Providing critically constructive instructor feedback at the start of the next class helps to close knowledge gaps and provide a connection between previous class prior knowledge and a gateway for upcoming class content learning. However, the source of some of the "muddiest points" may be from instructor blind spots (IBS) which can arise from lack of awareness or naïve assumptions about students' prior knowledge, including concepts, vocabulary, and skills, prior to joining a class. These IBS can be revealed from "muddiest points" and differ from knowledge gaps that arise during learning of new content. Using the IBS to alter teaching strategies and modify content can enhance learning outcomes such as attitude and persistence (7). This paper will discuss possible IBS in introductory materials courses, approaches to address them, and the impact on student learning.

Methodology

This paper will report results from "muddiest point" (MP) reflections on the different types of IBS with respect to different topics and possible sources of the IBS during the progression of an introductory materials course. In addition to the most recent results from spring term 2019, information from previous work and resources over the past decade will be incorporated into the discussion of the various IBS. The most recent data for this paper was drawn from a spring 2019 class. That and prior classes usually had enrollments between 35 and 70 students. This course has typically had students from engineering disciplines that were 65% mechanical, 15% materials, 10% chemical, and 10% industrial. Some of the details of the nature of the class, along with activities, assessment, and student resources are described below. The class levels of enrollment are typically 15% freshman, 30% sophomores, 25% juniors, and 30% seniors. The majority of students, juniors and seniors, have taken their freshman chemistry course two or three years earlier, so chemistry related concepts need to be reviewed and refreshed.

For classroom student engagement, there are group activity work sheets for each class which provide a pen and pencil worksheet that is used in conjunction with mini-lectures. Students work in groups of 3-5 students for 5-7 minutes and each of 8 to 12 group tables with one group member reporting out on their group's particular portion of the activity. Many of the worksheets are based upon "muddiest point" (MP) feedback that address student learning issues that have been previously identified. They help build students' vocabulary concepts, conceptual knowledge and problem solving skills. Sometimes there are also whiteboard activities included, especially for learning and drawing crystal structure, crystal directions and crystal planes. There are also "hands on" manipulatives that are occasionally used to help and improve spatial-visual skills of students, such as styrofoam crystal structures and ball and stick models of unit cells and defects. Information will also be drawn upon from assessment resources and results that have been used to characterize student learning issues. These include pre and post topic concept quizzes and results from various topics.

As a result of identification of student issues in vocabulary, concepts, skills, misconceptions, and instructor blind spots, a series of student support resources were also created that are available to students every year. These include the following. Concept and context maps were created for every topic in the course to show linkages between important topic concepts and real world contexts and help build students' vocabulary and topic conceptual understanding. Visual glossaries were also created for every topic that contain visual images of terms and concepts, as well as concise definitions. These are available to students on the Canvas learning platform. Similar sets of definitions are also available on the Quizlet.com web site for each topic which can be accessed with the Google key word, "matsciASU". Finally a series of 20 YouTube "Muddiest Point" tutorial videos, available at Google key word "materialsconcepts", were created over eight years that have received over 1.8 million views since 2012. This includes the most popular video on Eutectic Phase Diagrams which has over 600K views. These videos were based upon muddiest point feedback at the end of each class and address many of the most challenging topics in an introductory materials class. With the background described here in mind, we will report on some of the most prominent IBS revealed over many semesters of teaching and how they were addressed and what the possible impact was in terms of enhanced teaching and learning.

Results and Discussion

Atomic Bonding IBS

Early in an introductory materials course, the topics of the families of materials, periodic table, chemical bonding, and bonding as related to material properties are introduced. In an early class using MPs the author was somewhat surprised with the IBS that the majority of students were not familiar with bonding in terms of metallic bonding or van der Waals (VDW) secondary bonding. One student said "I thought Van der Waal bonds were a different kind of bonds since I never heard about them in Chemistry."(8) This was because prior chemistry courses focused mainly on ionic and covalent bonding and often did not mention metallic bonding and because mainly London dispersion forces may be described but do not mention that this attraction is one type of van der Waals forces. Once this IBS is revealed, VDW and metallic bonding can be defined and discussed early on in the first class. This is particularly important because VDW is very important in significantly affecting polymer properties because VDW results in much lower stiffness and melting point of polymers compared to metals and ceramics with primary metallic and covalent/ionic primary bonding. Once VDW was explicitly discussed in the first class, then the frequency of VDW occurring as a muddy point was reduced more than 40% over a four year span from 2010 to 2014.(8) It was also simpler to explain bonding-related property differences between polymers and metals and ceramics. Support for student learning on bonding was also provided in classroom activity worksheets, a visual glossary on vocabulary in Quizlet, and with a MP tutorial YouTube video.(7)

Materials Manufacturing Processes IBS

Another IBS in the early portion of a materials class is the general unfamiliarity of a majority of students with materials manufacturing processes, in spite of the fact that about half of a class is upperclass students with most of them in mechanical engineering. One student MP stated “I don't understand what the different "processes" are. I've never worked with what the processes of a material and bonding are.” In order to give value to learning about materials, the author’s class uses frequent examples of context with applications for different members of the families of materials, along with the associated manufacturing processes. Such processes, among many others used, include wire drawing and tube drawing for metals, sintering and slip casting for ceramics, and film blowing and extrusion for polymers. These processes are illustrated and defined in class slide sets and are often repeated in sections with more detailed discussions of metals, ceramics, and polymers. It seems that, over a progression of teaching over decades, students are less familiar with materials manufacturing processes, possibly because of a shift away from manufacturing interests of students. Be that as it may, it becomes more important to discuss in some detail some of the most frequently used processes. To support student learning in the area of materials processing there are entire classes devoted to metals processing, ceramics processing, and polymer processing, as well as a Canvas visual glossary, and vocabulary sets in Quizlet. Extra explanation and these resources have helped assuage concern and uncertainty for some students about their background and preparation for an introductory materials course. To inform students that processing methods may be new material and that they will learn it adequately over time also helps to lower anxiety.

Crystal Structures IBS

Another foundational topic area earlier in the course which can have IBS is crystal systems including structures, directions, planes, and defects. It can be that, in initially teaching in this area, an instructor might assume that engineering students have moderately developed spatial-visual skills, which is critical for developing material components, devices and systems. Such skills are also important in communicating with other engineers in a development team. It happens that the topical area of crystal systems is initially quite challenging for many students and geometry skills learned earlier may not translate well to the 3-D geometry of crystals. As such, it becomes necessary to show in explicit detail the 3-D features of cubes and representations of atomic level structures. To facilitate this it was found that manipulative 3-D styrofoam ball representation of hard sphere models of structures such as simple cubic, body-centered cubic, and face-centered cubic systems were quite helpful. Hands-on manipulation of such structures has helped clarify features such as close-packed directions, atomic packing factor and coordination number. Ball and stick models are useful manipulatives when teaching about indexing directions and planes in crystals, as well as illustrating important concepts such as metal slips systems. A critical hands-on activity is team whiteboards that student groups are challenged to use to draw or identify indices from for directions and planes. A concept quiz incorporating frequent misconceptions has been developed for (100), (110), and (111) planar packing for simple cubic, face-centered cubic, and body centered cubic systems (9). To support student learning there have been created classroom activity worksheets, a Canvas visual glossary, vocabulary in Quizlet, and an MP tutorial YouTube tutorial video on BCC unit cells.

Tensile Test IBS

Another type of IBS was revealed early on when muddiest points were first being collected on the topic of mechanical properties measured from the stress-strain graph of a tensile test. It had been assumed that students had well developed graph reading skills. But more than a third of 40 students made comments such as, "I wish it was more clear how to determine the properties." The material was explained again, seemingly to the students' satisfaction, but when the topic was taught again the following semester, a similar set of comments occurred. The principle features of the tensile test stress-strain curve are elastic modulus, 0.2% offset yield strength, tensile strength, breaking strength, and ductility in terms of % elongation (plastic). It had been assumed by the instructor, that when an example was given and discussed as to how to determine these values, that students would be able to carry out similar tasks. However, a significant fraction of the students were not and had difficulties with homework and tests that included the material. So a classroom activity was devised where, after the features of the tensile test were explained, the student groups themselves had to determine the values of the characteristic features of a tensile test by their group. Pairs of groups then reported out on the characteristic values and the process used to determine those values. After this type of class, comments on reading tensile test graphs dropped to a few. Students more easily solved their homework and did better on tests with tensile test questions. As with previous IBS topical issues, student support materials were created which included the described classroom activity worksheets, a Canvas visual glossary, vocabulary in Quizlet, and an MP tutorial YouTube video on determining mechanical properties from the tensile test stress-strain curve. These graph-reading skills were also found to be useful for other topics, such as property change versus treatment, e.g. change in tensile strength versus % cold work.

Phase Diagram IBS

A final IBS that was revealed from muddiest points occurred when the topics of phase diagrams and microstructures were covered in class. The topic of phase diagrams is considered by some instructors to be one of the more challenging in an introductory materials course. Comments from the muddiest points after the introductory lecture on phase diagrams were numerous and indicated that many students were moderately to considerably confused. Some of the comments included, "I don't quite get how to use a phase diagram all too well." and "How to differentiate alpha, beta and gamma phases." and "Defining what each line defines on the phase diagram can get slightly confusing." To be able to effectively understand and use phase diagrams requires use of multiple concepts, skills, and vocabulary. Some of these factors would include understanding how to read graphs, understanding definitions related to solid, liquid, and mixed phase regions and boundary lines, and the differences about solubility between liquid and solid phases related to concepts of undersaturated, saturated, and supersaturated liquid and solid solutions.

Clarification of differences in solid state phases at the onset of topic of phase diagrams is necessary because most students' experience about phases is from chemistry when solid, liquid and gas phases are studied. Differences in the nature of different solid state phases is a new concept and needs good definition and illustration. As an instructor it is possible to assume that students learned and understood differences in solubility of solids in liquids that were undersaturated, saturated, and supersaturated. Using pre and post topic concept quizzes around the topic of phase diagrams revealed a major misconception that students thought that a beaker of liquid with some solid at the bottom was supersaturated. They did not realize that the term "supersaturated" referred to the concept that, when there is excess solute in solvent, that the solvent is "supersaturated." An activity was created to address this misconception, but there was only a limited improvement (an increase in understanding from 40% to 60% on pre-post concept tests) in student conceptual understanding of a supersaturated liquid. However , when a YouTube video was shown to the class everyone watched closely (http://www.youtube.com/watch?v=1y3bKIOkcmk) and the student score on the concept quiz rose to 90% understanding of the concept of supersaturation (10). The video also illustrates the concept of the process of nucleation and growth that occurs in most phase changes. This concept of nucleation and growth is further driven home with videos for supercooled liquid crystallization with the video (http://www.youtube.com/watch?v=lISK1YFcZBM) and with superheated liquid (http://www.youtube.com/watch?v=2FcwRYfUBLM) which causes a minor steam explosion when superheated water explosively turns to steam.

Understanding the concept of a supersaturated solid is critical to explaining age-hardening of aluminum and other age-hardenable alloys. Understanding the concept is also useful in enhancing students' conceptual knowledge of solubility limits and lines on a phase diagram. Understanding the phase diagram concepts of solubility and of nucleation and growth of new phases is also critical in understanding how microstructures develop in steel, aluminum and other alloys. To support student learning for the five classes on phase diagrams there have been created classroom activity worksheets for each class, Canvas visual glossaries, vocabulary lists in Quizlet, and five MP tutorials with YouTube videos that have received over one million views in the last eight years.

Overall, the impact of addressing instructor blind spots from muddiest point feedback shows that it can help instructors address their own possibly faulty assumptions made about students' background when they take an introductory materials course. This new knowledge can result in modification of teaching materials and classroom teaching strategies. One new strategy being used is to ask the students at the beginning of class a general question or two about the day's topic, which can inform the instructor about prior knowledge of a topic or even familiarity with real world examples. As such, the use of a new or recent development in materials science, "Cutting Edge Technology," is being added to each class to improve the relevance of the course, as well as showing students the types of new materials, processes, or characterization that they might be using after graduation. Such topics have included atomic force microscopy (1 out of 40 familiar), scanning tunneling microscopy (1 out of 40 familiar), and additive manufacturing (0 out 40 familiar). Students have shown moderate to strong interest in discovering these recent developments in materials science that the instructor was not aware of the students' unfamiliarity with the topics.

Addressing IBS

Previous work has shown that addressing IBS and other student learning issues through muddiest point feedback can improve student learning and class persistence as well as attitude and attendance (7). Motivation can be improved when an instructor is aware of his or her own IBS and students' muddiest points by modifying class content as well as classroom teaching strategies and attitudes. Bandura's theory of motivation states that there are four primary positive motivating factors for students (11). These include content mastery and learning, vicarious learning (seeing other students succeed), positive reinforcement from an authority figure (instructor or teaching assistant) and classroom atmosphere. The end-of-course survey shown in Table 1 for the spring 2019 term reflects the positive attitude that students have in the engaged, participatory classroom. The survey was created with two sections. The first section is the use of teaching strategies to support student learning which used a five point Likert scale ranging from Strongly Disagree to Strongly Agree. The second part was a Personal Impact Survey to assess the impact of the class on the individual which used a five point Likert scale ranging from Strongly Disagree to Strongly Agree. Highlights of the results show the following. For Classroom Strategies the students felt strongly positive about: team activities and discussion; hands-on activities; and muddiest point discussion. They also viewed homework preview problems and muddiest point tutorial videos positively. They were 100% positive about the teaching aide supporting their learning. For Personal Impact students felt very positive about relevance to real world needs and moderately positive about: content being of value after graduation; increasing interest in their own major; and liking potential use of classroom strategies for other courses.

Table 1. Outcomes – Exit Survey (S19) Teaching Strategy and Personal Impact

Teaching strategies to Support Learning – Agree or Strongly Agree

- 1) 93% Team problem solving & discussion helped
- 2) 82% Hands-on activities supported learning
- 3) 97% Muddiest point next class discussion helped
- 4) 58% HW preview problem helped prepare for next class
- 5) 100% UG teaching assistant working with teams
- 6) 69% Muddiest point YouTube tutorials

Personal Impact Survey – Agree or Strongly Agree

- 1) 82% Increased interest in continuing in own major
- 2) 70% Content would be valued after graduation
- 3) 91% Saw engineering relevance to real world needs
- 4) 82% Would recommend class to a friend
- 5) 64% Would like instructional strategies in other courses

Summary and Conclusions

It has been shown how Instructor Blind Spots (IBS) revealed from student muddiest point reflections can be used to enhance the effectiveness of content delivery, classroom teaching strategies, and student achievement. The IBS have been broadly defined as instructor faulty assumptions of what instructors don't know about what students don't know, but assume, about students' prior knowledge of their vocabulary, problem solving skills, conceptual knowledge, and other facets of conceptual knowledge. The realization and uncovering of that knowledge can create opportunities for modifying content, altering classroom teaching strategies, and developing different types of resources to better support student motivation and learning.

A number of examples of IBS from an introductory materials class were cited along with strategies to address the IBS, along with evidence that learning and motivation were enhanced. The first example was the assumption that prior knowledge about bonding from previous chemistry instruction was well founded, but could lapse in time from instruction. There was also limited knowledge beyond ionic and covalent bonding which meant that additional instruction for metallic and van der Waals bonding would be useful. This helped provide a better understanding of key bonding-property relationships about the three families of materials, metals, ceramics, and polymers. A second area of IBS was found to be materials processing and manufacturing methods, which are closely related to the material family bonding under consideration. The connection between materials processing methods and the material family characteristics needs to be explained in conjunction with the processing to the shape of the final desired product. This is generally new material and new vocabulary for most students, so clear explanations and illustrations of the processing need to be articulated. Another example of IBS is the topic of crystal structures and the spatial visual skills that are useful in understanding the not only the different crystals structures, but also identification of features of the unit cell including identification and indexing of directions and planes and defects within crystal structures. Building visual-spatial skills with manipulatives and classroom activities enhanced understanding, as demonstrated by significant gains on pre-and-post concept quizzes.

Another topic that was affected by IBS is graph reading and interpretation skills necessary for characterization of mechanical properties of materials from the tensile test stress-strain curves. Although students may be used to interpreting mathematical relationships on a graph, they are less familiar with interpreting physical properties from testing results in engineering characterization of material properties. Although processes can be described for acquiring values of properties from a graph, it was found that a group activity was far more effective in developing the graph interpretation skills required. Finally, a last IBS was one associated with reading and interpreting data from phase diagrams. Although students have familiarity of solid, liquid, and gas phases of a material from chemistry, they have very limited knowledge of liquid-solid and solid-solid relationships as affected by temperature and composition for materials composed of more than a single element. Both terminology and concepts of phase diagrams may be unfamiliar to students, including solubility concepts of saturation and solubility limits at liquid-solid and solid-solid boundaries in phase diagrams. Classroom activities designed to define relationships through group work promote understanding, but additional student resources can provide substantial assistance with understanding phase diagrams. For all IBS topics discussed, student support resources were created to promote understanding included classroom activity worksheets, Canvas visual glossaries, vocabulary sections in Quizlet, and muddiest point tutorial YouTube videos.

It has been shown that an increased awareness of instructor blind spots revealed through muddiest point feedback can be utilized to modify content, classroom teaching strategies and create student support resources. These actions can result in enhanced student motivation, attitude, persistence and achievement. The effort to improve instruction takes continuing effort over time, months to years, but both student satisfaction with instruction, as well as instructor satisfaction with teaching will grow with time. For an instructor there will always be new challenges and opportunities for growth, both personally and professionally, with his or her instructional quality and achievement.

Acknowledgement

This work has been supported by the NSF IUSE program under Grant No. 1524527.

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