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Extending critical workforce competencies through sociotechnical educational partnerships

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Abstract— Aeronautics is a key sector of the US economy, but a sector facing a systematic challenge – maintaining a world-class engineering workforce. Global connectivity is leading to convergence of technology, products and partners and are driving new communication and collaborative competencies into the workforce. Content mobility and sophisticated mining and clickstream data analytics can leverage expert knowledge and disseminate critical knowledge to enable a rapid "up skilling" of evolving workforce competencies. These Hyper Connected Manufacturing trends will interconnect our education content, design methods including production engineering and supply chain systems. Business pressures, innovation and competition are surfacing emergent competencies which will required rapid re-tooling of workforce competencies. These sociotechnical forces will transform organizational structure, education content, outcome analytics, and management methodologies. Research to understand this eco-system and the impact to our value chain are critical and include new processes and tools that will allow us to collaborate more efficiently, surface new patterns, and act to exploit the opportunities. These trends are global and have saleable opportunities but will require mega-trend champions and competencies aligned teams to understand and exploit these opportunities. In this vein, The Boeing Company partnered, in 2013, with the University of Washington to implement an industry – academia, Massive Open On-line Course (MOOC) titled "Introduction to Composites for Engineers.

Index Terms—Industry-academia partnership, online education, data analytics, scalable learning

I. INTRODUCTION

In the current knowledge economy companies are constantly facing a battle to innovate or die. This continuous innovation requires a commitment to lifelong learning[1]. In 2013 Boeing employees completed more than 6.5 Million hours of instruction from a portfolio of over 12,000 engineering and non-engineering courses. One of these courses is an introductory course in composites, which is offered in collaboration with the University of Washington Aerospace and Aeronautical School. While demand for the course is high; student learning and course delivery both exemplary, there are basic issues with access and scalability with regard to this and other courses like it. First, the course is limited to 25 students at a time in a limited geographic area, and second, students even though they meet the professor face-to-face, they get one shot at the professors lectures. As a global company, and with strategic partnerships in many continents this model is not scalable. Thus, this academia-industry partnership developed an online version of the popular Introduction to Composites course, which is delivered via edX to employees and suppliers disregarding geographical boundaries.

In this MOOC we produced an introductory course on composite materials that is currently taught at the University of Washington Aerospace and Aeronautics and Engineering School, into an online interactive course aligned to MIT's edX platform principles of information processing and dissemination. The goal was twofold: primarily, we wished to disseminate the expertise of the composites professor to worldwide audiences, so that more than just one classroom at a time would be able to share his knowledge and expertise; and secondly, we wished to install this online course as a gateway to introduce prospective composites workers from anywhere in the world to the engineering pipeline for composites manufacturing in aerospace. The obvious advantages of using a MOOC are incontrovertible.

Composites are used in many industries today to enable high-performance products at economic advantage. These industries range from space (International Space Station) to sports (Golf, sailing skiing) and include manufactured products for aircraft, transportation, energy, construction, sports, marine, and medical use. There are many material, economic, and aesthetic advantages to using composites over metals, and indeed much of this course outlines the differences, the advantages and the disadvantages of using one over the other. However, with regard to using composites over metals, it is suggested that a solid knowledge of the physical properties, including areas of mechanics, tooling, design, inspection and repair, and manufacturing options is required for working in this medium as these separate areas are intrinsically linked.

This paper describes the history and framework of the partnership in developing this course in a demanding technical area; addresses the underlying pedagogical intentionality of course development, as well as provide an initial analysis of the interactions of the more than 12,000 students.

II. PARTNERSHIP

The Boeing Company thrives on the technical excellence of its global diverse workforce. While significant experience resides with subject matter experts (SME's) within the various divisions inside the enterprise, there has been a longstanding tradition for Boeing to partner with universities around the globe. These partnerships provide a bidirectional benefit to all parties regarding workforce development, research, and knowledge sharing.

Regarding workforce development these partnerships play a critical role, since industry feedback can help provide guidelines for academic programs and training for future needs. In this role, the growth of online education (MOOCs) is hard to ignore. Industry is fast following academia in embracing distance education, in particular the flexibility and scalability of MOOCs. More often than not, it is a collaborative venture between academia and industry that facilitates new material in this arena.[2] According to data compiled by the Integrated Postsecondary Education Data System, about 5.5 million students took at least one online course in Fall 2013 and more than 80% of public universities and half of private colleges offered at least one fully online program.[3] Over the past ten or so years Prof Lin (the content expert in this MOOC) has taught the course Introduction to Composites every year and reached 300 students, yet in one 12-week course, he was able to reach 15,000 students alone and, with a little advertising and application, the potential is self evident.

Driven by the overriding question; What does it take to present first rate on-line courses that drive quality into student learning experience, the design team intentionally obviated the old model where one size fits all learners. Instead, they embraced a course construction model that connected innovative instructional units so that they were adaptable and personalized for student engagement. In addition, this model allowed big data click-stream events to predict outcomes, which facilitated easy adapting to learner pathways. The development team was quick to recognize that face-to-face instruction doesn't always directly translate into what students need in an online environment, and devised to make deliberate effort to incorporate best practices from learning sciences and pedagogical frameworks that are known to be successful in this industry [4,5].

Industry doesn't necessarily know instructional design best practices, teaching methodologies and strategies that work. This is where industry/academic partnerships like Boeing and the University of Washington bring their accumulated experience – large scale integration experts, in addition to best practices in learning and teaching, within a model of driving effective business results. In this Composites MOOC production industry and academic experts worked within an intentional framework to carefully blend the highest standard content with pedagogical models from learning sciences so that the presentation incorporated active learning, student engagement, feedback and self-efficacy. This involved a plan to drive fidelity into the process; to insure compliance with regional accreditation standards by partnering with proven academic institutions like the University of Washington's Professional and Continuing Education group and MIT's EdX platform. Further, the plan incorporated intentional quality and simplicity by maintaining a discipline and rigor during course creation, test, and implementation.

Delivery of content via MOOC has a number of great advantages over traditional mechanisms that are rooted to place and time. Some of these advantages are made explicit in areas that are not always either planned or expected and increase versatility for the teacher, the student and the company that is supplying the content. The great advantage for Boeing is that product engineers can guarantee that new hires who take this course already come prepared for work, and specifically, prepared for more and focused learning in the composites field. In similar fashion, a great advantage for the student is that, unlike in traditional courses where students experience the lecture only one time (teacher paced), in the online model the student can view the course as many times as is needed (self-paced) in order to reach competency. This default paedocentric approach fosters a sense of agency in the student and promotes self-efficacy and deep understanding since learners are in control of pace, location, space and time. Students are essentially in charge of all the ingredients to control their own learning.[6] The up-front cost of development pays off over time since both the professor and the production team learn how to craft meaningful courses very quickly. Access to click-stream data is opening up a new field of data mining for learning so that our research team have more predictive power over what courses to produce and what students would benefit from what kind of course.[7]

Course Objectives were planned to align with learning and knowledge acquisition so that students not only had a good experience on the edX platform but also followed through and learned meaningfully from the course. After completing this course, it is envisioned that students will be able to: (i) demonstrate understanding of fundamental principles in areas pertaining to composites in aerospace design/manufacturing; including knowledge of materials, manufacturing, mechanics, design, repair of polymeric matrix composites; (ii) identify important advantages and disadvantages of polymeric matrix composites with respect to metals; (iii) apply knowledge acquired to the design and manufacturing of high-performance composite structures.

III. History

Kathleen

IV. Scalability

Fabian, Kathleen

V. Structure and Pedagogy

As technologies make this medium (Composites) more attractive to manufacturers and more desirable than metals (because of weight, strength, durability, fuel efficiency, and much more) for building modern aircraft, composites manufacturing is a critical new element to aircraft design and assembly. Consequently, the growth and feasibility of reaching larger audiences with MOOCs has become a desirable sector of the learning community. From that standpoint, we are increasingly desirous of learning some of the advantages and pitfalls associated with large learning cohorts and advanced technical content that is structured to be accessible and indeed learnable. We are intrigued by the opportunities this new medium offers the teaching and learning community.

To develop new composites teaching materials, content experts engaged in careful analysis of what topics were to be taught. Further, working with learning scientists these experts were able to isolate and contextualize the enduring ideas associated with composites material manufacturing in aerospace.[8] Course content was placed on PowerPoint slides and the instructors, plus several subject matter experts (SMEs), vetted the provenance and accuracy of each slide's content by resolving any disagreements. Each slide was presented and explained by the lead professor, who maintains a technical, pivotal presence throughout the MOOC. The course development team included curriculum designers, videographers and learning scientists who defined the learning objects and aligned them with pre-existing edX platform constraints.

Targeted learning sciences thinking[9] and *How People Learn* principles[10] were incorporated into the design at every opportunity. First, content was analyzed for alignment to learning objectives and "enduring" big ideas—maintaining a backwards design approach.[8] In other words, this helps delineate a clear picture of the information that the professor would like the student to walk away with (having viewed the video and working through any examples and quizzes). In adherence to brain-based learning principles, all content concepts were intentionally connected to one of the several big ideas that the subject matter experts agreed upon. In this way we were planning to avoid disconnected inert knowledge acquisition by the learner.[11]

A deeper understanding of what it means to create MOOC material in a HPL framework would look like this. Essentially the elements of HPL involve four critical over locking and interlocking Venn diagrams that focus on aspects of teaching and learning meaningful to learning with deep understanding. This kind of learning is the ultimate design of learning establishments. Long have we passed the time where simply tossing the information at the student hoping that it might stick will suffice? Such arcane practices have been replaced with ideas and strategies within the field of the learning sciences that propel agency and metacognition to the forefront of pedagogical tools. How then does one create online classes that have elements of metacognition and agency associated with them?

We describe four components that comprise the HPL framework as they are operationalized as constructs in designing the video inputs. The four components relate to four centers of focus for how educational experts organize what is known about teaching and learning. While acknowledging that the centers are best viewed as an interconnected and intercepting whole, it is useful to distinguish each facet in an effort to align learning and teaching components in the production of videos. With MOOCs it is difficult to envision a community-centered environment in a way that resembles what is described by Bransford in his oeuvre on How People Learn.[10] Traditionally, a safe environment is one where norms are established, where learners can learn in safety as individuals and/or from/with their peers. Naturally, all systems typically associated with a fixed classroom in a defined geographical space are neither desirable nor practicable with regard to MOOC delivery mechanisms. However, a classroom community construct is still an appropriate way to ask questions about learning systems and student interaction. This is particularly so from the perspective of social norms that allow students the freedom to make mistakes in order to learn from their experiences [12,13] while at the same time seeing themselves as part of a community of learners with regard to the course. In a traditional classroom setting, the students engage in a real time one-on-one encounter with the teacher. This is impossible with a MOOC. Students are forced to engage with a movie or video clip that usually represents the head, voice and content of the teacher. Questions remain as to the effectiveness of this mode of information dissemination and the engagement level and outcomes for the students. It is our contention that a video production in a MOOC setting that is intentional about incorporating some of the more meaningful elements of the HPL model will have a positive outcome for the students. We outline four interlocking environments that comprise an HPL framework for learning and teaching: first, a learner-centered environment that connects with a knowledge-centered environment and an assessment-centered environment, each existing within a community-centered environment. The four environments relate to four centers of focus for how educational experts organize what is known about teaching and learning today.

A learner-centered component of the HPL framework defines an operational construct for understanding the instructional dynamic in operation in the MOOC. One of the questions that educators have for MOOCs centers on if we can elicit information pertaining to knowledge, skills, attitudes, and beliefs pertaining to learners in a distributed educational setting. According to Bransford, et al., teachers who are learner centered "…recognize the importance of building on the conceptual and cultural knowledge that students bring with them to the classroom."[10] This involves an intentional 'making visible' of implicit preconceived ideas, prior knowledge and misconceptions that the student brings to the table.

Knowledge Centered environments allow experts in content areas prepare and deliver timely, contextual information to students. Knowledge of all kinds is essential for students to be successful and effective in twenty-first century living. However, teachers are aware and it is well documented that knowledge in, and of itself (e.g., inert knowledge), is of little use in this regard[11], remaining inert and disconnected (essentially taking up space in the brain). But knowledge that is connected, contextual, and well-organized leads to learning with understanding[8] where students are able to make meaning by connecting their prior knowledge to new information that is constructed in a way that offers both logic and meaning. This kind of learning with deep understanding (including concepts and ideas) affords a versatile ability to transfer ability and skills to new and unplanned situations[14,15] and contributes to conceptual change.[16,17] Knowledge-Centered environments when carefully thought out therefore, help students with cognitive rehearsal[1] so that they increase their skills in transfer by attaining a flexible adaptation[18] to new problems and settings.

Assessment Centered learning environments provide opportunities for feedback and revision so that teaching can be optimized for the learner[14,18]. We distinguish between two major forms of assessment—*Formative Assessment* and *Summative Assessment*. Each has particular functionality for enhancing the learner environment and specifically for aiding the teacher in monitoring and maintaining healthy learning environments. Formative assessments involve a deliberate use of techniques that deliver immediate feedback in the context of classroom teaching and are useful to make the teacher aware of the pace and capacity of the learner. On the other hand, summative assessments measure what students have learned at the end of a set of learning activities.

This same framework helps us formulate the leading questions that we wish to investigate in this research design. Do learners engage in a particular video when Learning Science principles are added to the construction process? Do learners engage differently to a video when there are learning science components included—like scaffolds, animations, new voice, novelty? Can we isolate and focus on a particular exemplar video to ascertain what works and what doesn't?

We have learned much about Massive Online Open Course (MOOC) preparation and delivery from past studies. There is a tendency for the public and some academic insiders to crown MOOCs as a disruptive force that is going to transform education., with some people stating that this innovation is no less radical than the printing press.[7] For instance, from work presented at the *International Conference on Learning Analytics and Knowledge*, we expect that most students will audit their MOOC, simply engaging primarily with videos while skipping over assessment problems, online discussions, and other interactive course components.[19] We also know that videos are important as verified by researchers of the Association for Computing Machinery who testify that in the first edX course (6.002x, Circuits and Electronics) students spent the majority of their time watching videos.[3,20] In addition, while video consumption has never been so popular there is increased demand for instructional type videos. For instance, in the past decade, free online video hosting services such as YouTube have enabled people to disseminate instructional videos at scale.[21] Borderless higher education (like that provided by exposure to MOOCs) is acknowledged as a driver for economic growth not only in developed countries but reaching into distant places where access and opportunity are critical mainstays of industrial growth.[2]

When it comes to learning from videos engagement is important.[22] Many researchers have focused on video production and video delivery mechanisms/formats by way of understanding engagement in MOOCs. For instance, Illoudi et al., showed that students held a slight preference for classroom lecture videos over Khan-style videos.[22]

For many of these studies the unit of analysis is engagement. Engagement is measured by focusing on video clips, which are used throughout the course to present new information to participants. Video clips have been used in other studies to gain information about how students are interacting and therefore engaging with the content that is being transmitted.[23] Video viewing has become a central aspect of learning in todays world, where teachers, students, parents, children and various grouping of these see great value in exploiting material on the web that is presented via video.[21] Videos are unique as units of analysis since one can discern who is watching it, when they initiated the video, how long they stayed on the video and whether or not they finished it. Added to this descriptive data are correlational data pertaining to the content of the video, how it was made, what methods were used to make it accessible and comprehensible for the user and so on. For instance, when videos are intentionally created with end-user goals firmly in mind, what is the likelihood of more and better engagement? Finally, performance in and indeed attention to quizzes that are associated with a particular video presentation can be correlated with a view to measuring the learning outcomes as a result.

With regard to using videos as units of analysis, earlier research findings confirm what many educators suspected all along. There is ample evidence that shorter, lively videos are much more engaging than long boring videos; informal talking-head videos can be engaging if the speaker is entertaining and if the material is relevant; Khan-style tablet drawings are engaging at times, even high quality pre-recorded classroom lectures might not make for engaging online videos; and students engage differently with lecture and tutorial videos.[23]

As with most everything in life, attention is critical. Defined as allocation of processing resources, we only attend to what we perceive as important. However, learning scientists who are aware of principles of how the brain works and how attention connects with understanding, should be able to build-in elements and activities that scaffold the attentional affordances for learners. These attentional techniques are based on neuro-scientific principles of understanding attention: alerting, orienting and executive.[24] One of the critical aspects of MOOC video construction appears to be whether or not the content has direct meaning for the learner; whether the material is engaging enough for the individual to persist through course modules; and whether the rewards for staying the course are sufficient to maintain residency.

VI. Data and Findings

A. Data Collection

This paper describes the history and framework of the partnership in developing this course in a demanding technical area; addresses the underlying pedagogical intentionality of course development, as well as provide an in-depth analysis of discernible interactions of the 12,000 students. In this study, data is collected through edX's back-end clickstream engine. Data pertains to if, when, how, and how long students watch each video, and whether they attempt to answer post video assessment problems. This clickstream data make it possible for us to investigate questions relating to which videos were watched, for how long, if paused, re-viewed and so forth.

A typical video production is described here together with the elements of pedagogy that we think are critical for participant learners to stay the course and achieve success. Each video is presented through the edX dashboard, which is typical of many MOOC productions, allowing users to personalize and arrange materials to suit their own needs. With regard to the production of the video we look at a video from Module Four, which is in the middle of an eight-module presentment about the topic in hand—Introduction to Composites for Aerospace. The video (again staying true to a carefully prepared pedagogical intentionality) is one minute and 40 seconds in length. We consider videos that are more than 2 minutes in length to be a stretch to the learners capacity (based on neuroscience findings—see: Miller[25])

In addition, data is captured that describes the demographic information about the participants taking the courseware—including geographic dispersal, gender, age, fluency with English, level of education, knowledge of engineering, history and experience with MOOCs and more. Data was also captured regarding quizzes that were associated with some videos and chapters. These data can be correlated with video data (just described) in order to assess if particular video styles or quiz styles had better (or worse) outcomes for learners. Data is obtained in large J-span files that need to be converted to appropriate format for reading into other software programs like Excel and SPSS etc.

B. Results

Victor, Fabian

Access over time line graph (video, assessment, forum, wiki)

Time on task per week for different course elements

Graph showing how many graduates accessed what percentage of resources (break down separately into histogram for views of lecture video and assessments)

Map with geographic distribution
Age demographics histogram

Educational background

Persistence graph

Box and whisker plot for grade in course vs. how students worked or level of education

Video length to engagement of students

VII. Conclusion

In this paper we describe a MOOC, which first appeared as a face-to-face course at the University of Washington. This course was translated into a MOOC in order to reach a wider audience of potential Composites workers in the aerospace industry. We chose MIT's edX platform to reach that audience and to gain access to the data analytics that their engine produces.

Several outcomes are immediately visible to us as a result of this undertaking. First, this online course was immediately and forever available to large numbers of individuals who appear to be interested in the topic: Introduction to Composites for the Aerospace Industry. Further this course was free to these individuals. Many outcomes are less obvious, but a little digging under the hood (with the aid of data analytics) demonstrates a number of very important features. Approximately 10% of the initial students who signed in to the course actually finished the course. This accounts for a large number of people distributed across 20 countries from around the world. This number is also much higher than the 3% or so that early MOOC courses tended to maintain. This success we attribute to the intentionality of video preparation by embedding pedagogical thinking into big ideas and concept maps that help the user stay connected and engaged. While some MOOC models tend to focus on the social aspect of learning (e.g., through social media Facebook-style interactions and deliveries) we chose to give weight to pedagogical tools (e.g., Backwards Design) and brain-based methodologies (e.g., connecting big ideas to each concept) so that the learner might stay engaged and willing to persist online.

Inflection points in the data indicate that where pedagogy and content were aligned in this way, the learner appeared to stay engaged, finished the video and answered the quizzes associated with it. The fact that videos were available for learners to view at their own speed, on their own time, and whenever they wanted to, indicates that learner agency was engaged. We know that when learner agency is engaged, the chances for learning with deep understanding are increased.

In view of this initial success with on-line distance learning (MOOCs) we are encouraged to persevere with a model that grows our academic industrial partnership so that we are better equipped to not only survive the current knowledge economy but, through innovative learning models, thrive and prosper.

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The preferred spelling of the word "acknowledgment" in America is without an "e" after the "g." Try to avoid the stilted expression, "One of us (R.B.G.) thanks ..." Instead, try "R.B.G. thanks ..."

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Questions that we are attempting to connect to the data…

- What is the persistence of students over the duration of the course?
- How are students doing on the course assessments? Is this related to the video (e.g. length, type)?
    - Assessments can be linked back to learning objectives and videos in the course. Are we covering all objectives and are all videos successful in increasing learning?
- What does the temporal behavior of the students look like? How are they accessing the course material, in small chunks, in large pieces? - Access over time line graph (video, assessment)
    - Might be able to get some additional data on forum access here
- What differentiated the people who finished the course from people who didn't? What are the usage patterns of the people that did finish the course? - Graph showing how many graduates accessed what percentage of resources (break down separately into histogram for views of lecture video and assessments)
- How does performance on assessment differ between course completers and "lurkers"?
- Where are people accessing this course from? - Map with geographic distribution (IP provided)
- For individual videos, what cause students to pause, stop, fast forward? Is there a correlation to words/minute spoken by the instructor?
    - I have all the videos, but do not have a big enough file share, they are about 13GB. I am also working on getting a copy of the existing transcripts.

Questions for Tableau

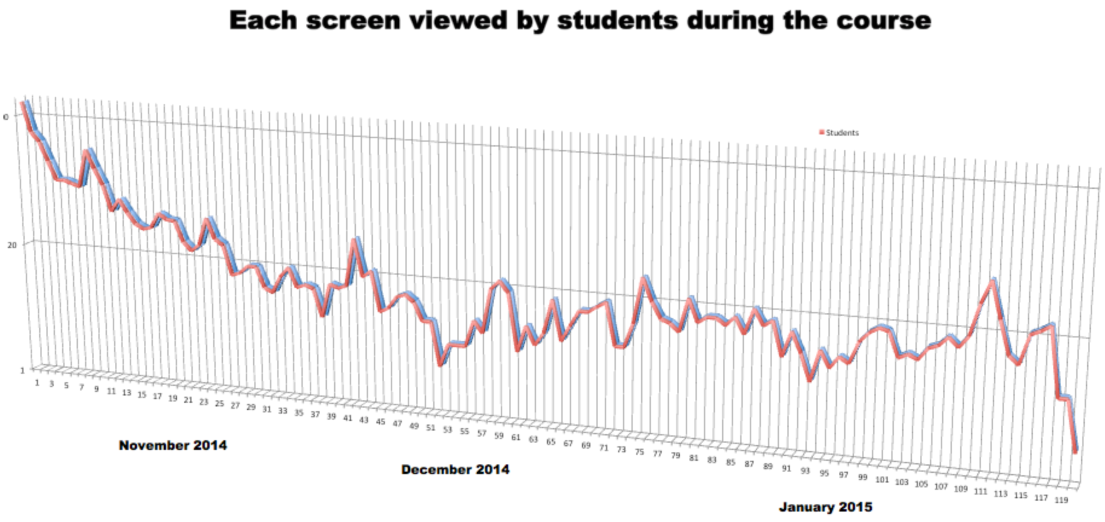
We are trying to understand user engagement – to connect with how the videos were built by incorporating learning sciences pedagogical principles. We would like to understand if they were impactful and or effective. We were very intentional about how the videos were put together. We tried to chunk the content so that videos are short. At the same time when we couldn't have short videos, we tried to insure that all content in longer videos connected directly to the one Big Idea that was central to the content information. Every video focused on one Big Idea. We provided a narrator who was expert and whose personality was central to the entire production – 120 videos. We wanted to minimize any talking-head input and vary it with colorful pictures and other voices where possible.

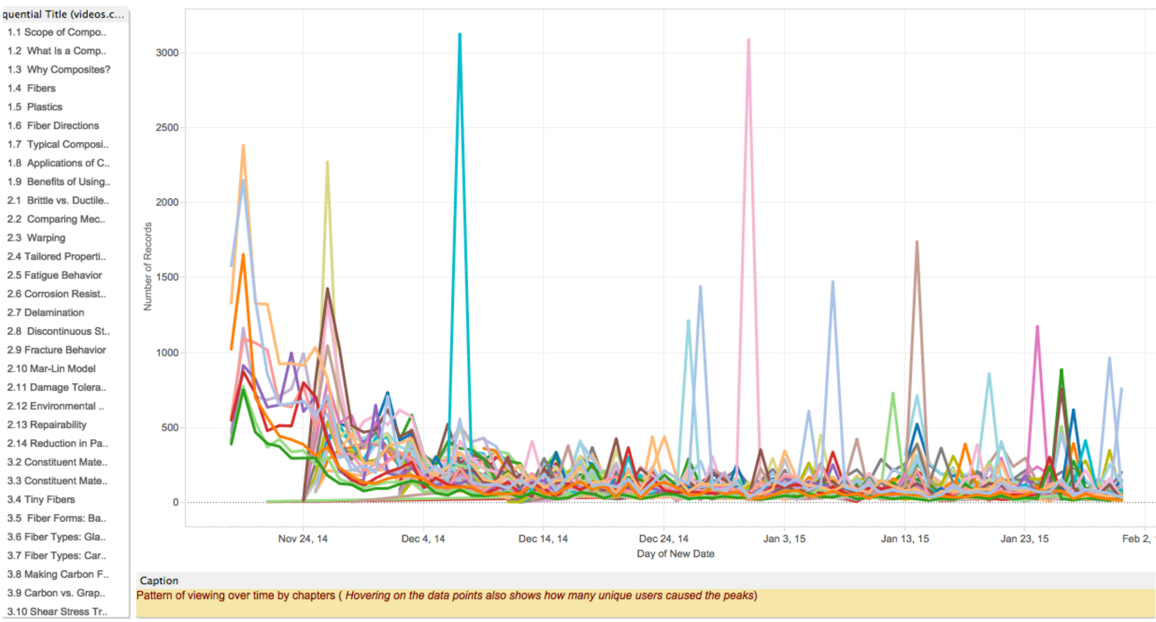
In order to find out if this all worked we need to ask questions that get at these items. Here is a start. We need to have a common vocabulary about these data so that we know what we mean when we refer to items and events etc. For instance, a lot of my vocabulary will include learning sciences terminology and pedagogical terminology and might need to be translated into Data Analytics and what we can do together to unpack the data in this sphere.

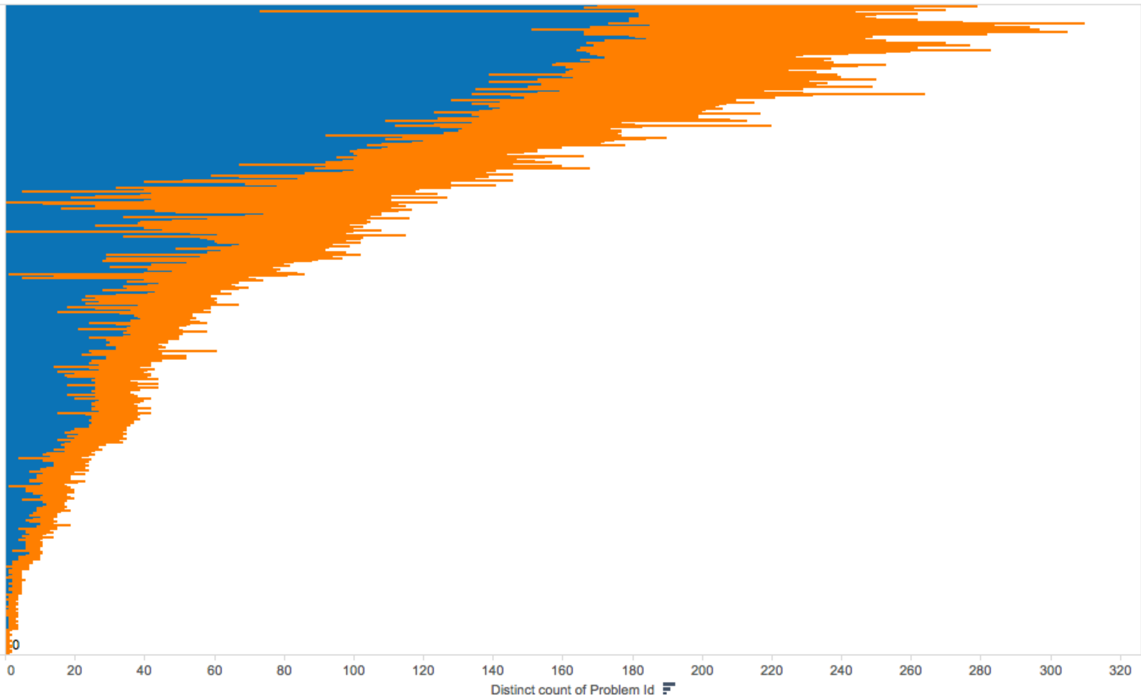
Engagement is a big issue. We would have to define engagement as initiating a video, finishing a video, maybe revisiting that same video and completing the quiz associated with that video.

1. Need demographic breakdown – Do we know who took the course, gender, age, degree, etc., any info on the participants
2. Need a list of all videos by name and length vs. number of students who (i) started each video, (ii) who finished that video, and (iii) who finished with quiz complete and correct)
3. Need to know the attrition pattern – was there an inflection point?
4. Let's start there….. there will be more

Figures


Each screen viewed by students during the course
Students
November 2014
December 2014
January 2015


quential Title (videos.c...
1.1 Scope of Compo..
1.2 What Is a Comp..
1.3 Why Composites?
1.4 Fibers
1.5 Plastics
1.6 Fiber Directions
1.7 Typical Composi..
1.8 Applications of C..
1.9 Benefits of Using..
2.1 Brittle vs. Ductile..
2.2 Comparing Mec..
2.3 Warping
2.4 Tailored Properti..
2.5 Fatigue Behavior
2.6 Corrosion Resist..
2.7 Delamination
2.8 Discontinuous St..
2.9 Fracture Behavior
2.10 Mar-Lin Model
2.11 Damage Tolera..
2.12 Environmental ..
2.13 Repairability
2.14 Reduction in Pa..
3.2 Constituent Mate..
3.3 Constituent Mate..
3.4 Tiny Fibers
3.5 Fiber Forms: Ba..
3.6 Fiber Types: Gla..
3.7 Fiber Types: Car..
3.8 Making Carbon F..
3.9 Carbon vs. Grap..
3.10 Shear Stress Tr..
Number of Records
Nov 24, 14
Dec 4, 14
Dec 14, 14
Dec 24, 14
Jan 3, 15
Jan 13, 15
Jan 23, 15
Feb 2,
Day of New Date
Caption
Pattern of viewing over time by chapters (Hovering on the data points also shows how many unique users caused the peaks)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220
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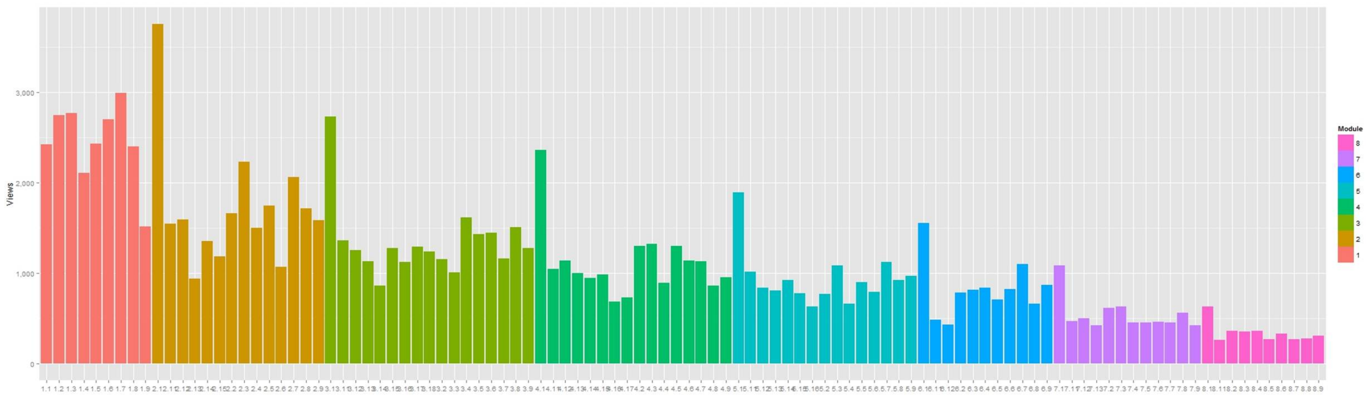
320
Distinct count of Problem Id


Views
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2,000
3,000
Module

Appendix
List of Files and times

Week 1	
CMOFE Lin 1.1 ScopeOfCompositeMaterial_FINAL	4:48
CMOFE Lin 1.2 WhatIsAComposite FINAL	2:17
CMOFE Lin 1.3 WhyComposites FINAL	6:36
CMOFE Lin 1.4 Fibers FINAL	:49
CMOFE Lin 1.5 Plastic FINAL	:45
CMOFE Lin 1.6 FiberDirections FINAL	2:30
CMOFE Lin 1.7 TypicalCompositeMaterialForms FINAL	3:34
CMOFE Lin 1.8 ApplicationsOfCompositeMaterials FINAL	4:27
CMOFE Lin 1.9 AdvantagesOfCompositesForAircraftStructures-UsageAndGrowthInIndustry FINAL	6:24
Week 2	
CMOFE Lin 2.1 Brittle vs Ductile Materials FINAL	4:26
CMOFE Lin 2.2 Anisotropic Behavior FINAL	4:40
CMOFE Lin 2.3 Buckling and Bending FINAL	2:20
CMOFE Lin 2.4 Tailored Properties FINAL	9:55
CMOFE Lin 2.5 Fatigue Behavior FINAL	5:00
CMOFE Lin 2.6 Corrosion Resistance FINAL	2:28
CMOFE Lin 2.7 Delamination FINAL	3:01
CMOFE Lin 2.8 DiscontinuousStress FINAL	3:22
CMOFE Lin 2.9 Fracture Behavior FINAL	4:18
CMOFE Lin 2.10 Mar-Lin Model FINAL	5:46
CMOFE Lin 2.11 Damage Tolerance FINAL	7:02
CMOFE Lin 2.12 Environmental Effects FINAL	3:59
CMOFE Lin 2.13 Reduction In Part Counts FINAL	2:01
CMOFE Lin 2.14 Repairability FINAL	5:05
CMOFE Lin 2.15 Summary FINAL	7:42
Week 3	
CMOFE Lin 3.1 Overview FINAL	1:36
CMOFE Lin 3.2 Constituents Fiber FINAL	3:24
CMOFE Lin 3.3 Constituents Matrix FINAL	2:11
CMOFE Lin 3.4 Tiny Fibers FINAL	1:27
CMOFE Lin 3.5 Terminology FINAL	2:10
CMOFE Lin 3.6 Glass Fiber FINAL	1:35
CMOFE Lin 3.7 Carbon Fiber FINAL	4:02
CMOFE Lin 3.8 Making Carbon Fibers FINAL	3:54
CMOFE Lin 3.9 Graphite vs. Carbon Fiber FINAL	:43
CMOFE Lin 3.10 Shear Stress Transfer FINAL	1:49
CMOFE Lin 3.11 Intro to Matrix FINAL	3:41
CMOFE Lin 3.12 Types of Matrix FINAL	2:23
CMOFE Lin 3.13 Polymers FINAL	3:09
CMOFE Lin 3.14 Thermoset Polymers FINAL	1:26
CMOFE Lin 3.15 Glass Transition Temperature FINAL	2:40

CMOFE Lin 3.16 Thermoplastic Polymers FINAL	5:01
CMOFE Lin 3.17 How to make a Prepreg FINAL	2:01
CMOFE Lin 3.18 Environmental Effects FINAL	2:37
WEEK 4	
CMOFE Lin 4.1 Learning Objectives FINAL	1:20
CMOFE Lin 4.2 Intro to Manufacturing and Curing FINAL	3:09
CMOFE Lin 4.3 Viscosity, Gel Time FINAL	2:48
CMOFE Lin 4.4 Resin Flow, Shrinkage, FINAL	2:02
CMOFE Lin 4.5 Manufacturing Terms FINAL	3:23
CMOFE Lin 4.6 Hand Layup FINAL	3:55
CMOFE Lin 4.7 Autoclave and the Curing Cycles FINAL	4:16
CMOFE Lin 4.8 Microstructure of CFRP FINAL	1:47
CMOFE Lin 4.9 Automated Layup FINAL	1:59
CMOFE Lin 4.10 Resin Infusion Toughened Epoxy REVISED	1:15
CMOFE Lin 4.11 Resin Transfer Molding FINAL	1:39
CMOFE Lin 4.12 VARTM FINAL	2:02
CMOFE Lin 4.13 Thermoplastic FINAL	1:15
CMOFE Lin 4.14 Tooling FINAL	4:14
CMOFE Lin 4.15 Common Autoclave Curing Problems FINAL	2:08
CMOFE Lin 4.16 Tooling Materials FINAL	3:36
CMOFE Lin 4.17 Summary FINAL	3:02
WEEK 5	
CMOFE Lin 5.0 Weekly Intro	:49
CMOFE Lin 5.1 Overview FINAL	1:05
CMOFE Lin 5.2 Definition of Stress FINAL	2:49
CMOFE Lin 5.3 2D Stress FINAL	2:34
CMOFE Lin 5.4 3D Stress FINAL	1:29
CMOFE Lin 5.5 Strain FINAL	2:13
CMOFE Lin 5.6 3D Strain FINAL	1:51
CMOFE Lin 5.7 Isotropic Material, unixial testing, Hook's Law, Poisson's Ratio FINAL	2:25
CMOFE Lin 5.8 Hooke's Law for Isotropic Material FINAL	3:40
CMOFE Lin 5.9 Orthotropic Materials FINAL	3:09
CMOFE Lin 5.10 Elastic Constants FINAL	3:40
CMOFE Lin 5.11 Hooke's Law for Unidirectional Composites FINAL	2:20
CMOFE Lin 5.12 Free Thermal Strain FINAL	2:42
CMOFE Lin 5.13 Effects of Moisture FINAL	1:33
CMOFE Lin 5.14 Hooke's Law for UD FINAL	2:10
CMOFE Lin 5.15 Elastic Constants and Gxy 45° Shear Modulus FINAL	2:01
CMOFE Lin 5.16 Summary FINAL	:26
WEEK 6	
CMOFE Lin 6.0 Weekly Intro	:34
CMOFE Lin 6.1 Intro FINAL	1:10
CMOFE Lin 6.2 Lamina vs Laminate FINAL	1:33
CMOFE Lin 6.3 Staking Squence FINAL	:42
CMOFE Lin 6.4 Constructing a Multiangle Laminate FINAL	2:13

CMOFE Lin 6.5 Symmetric Laminate Notation FINAL	3:00
CMOFE Lin 6.6 Unsymmetric Laminate Notation FINAL	2:02
CMOFE Lin 6.7 Classical Lamination Theory FINAL	5:42
CMOFE Lin 6.8 Applications of CLT FINAL	2:38
CMOFE Lin 6.9 CLT Examples FINAL	3:06
CMOFE Lin 6.10 Quasi-Isotropic Laminate FINAL	2:58
CMOFE Lin 6.11 Using CLT to Predict Laminte Properties FINAL	4:38
CMOFE Lin 6.12 Summary FINAL	:53
WEEK 7	
CMOFE Lin 7.0 Luke Weekly Intro FINAL	:28
CMOFE Lin 7.1 Learning Objectives FINAL	:33
CMOFE Lin 7.2 Impact Dmage FINAL	2:14
CMOFE Lin 7.3 Impact Types FINAL	2:42
CMOFE Lin 7.4 Visual Inspection FINAL	1:40
CMOFE Lin 7.5 NDI - Ultrasonics FINAL	1:19
CMOFE Lin 7.6 NDI- Thermography FINAL	2:29
CMOFE Lin 7.7 Temporary Structure Repair FINAL	1:02
CMOFE Lin 7.8 Wet Layup Repair FINAL	:45
CMOFE Lin 7.9 Pre-Preg Layup Repair FINAL	:50
CMOFE Lin 7.10 Bolted vs. Bonded Repair FINAL	1:46
CMOFE Lin 7.11 Bonded Repair Types FINAL	1:20
CMOFE Lin 7.12 Scarf Repair FINAL	1:42
CMOFE Lin 7.13 Summary FINAL	:59
WEEK 8	
CMOFE Lin 8.0 Luke Weekly Intro FINAL	:42
CMOFE Lin 8.1 Learning Objectives FINAL	:27
CMOFE Lin 8.2 Design Philosophy FINAL	4:08
CMOFE Lin 8.3 Cost Study Metal vs. Composites FINAL	2:01
CMOFE Lin 8.4 Metal vs. Composite Design FINAL	1:14
CMOFE Lin 8.5 General Design Considerations FINAL	2:12
CMOFE Lin 8.6 Thickness Changes FINAL	:38
CMOFE Lin 8.7 Potential Problem Areas FINAL	2:31
CMOFE Lin 8.8 Design Choices FINAL	3:25
CMOFE Lin 8.9 Designing Complex Parts FINAL	2:39
CMOFE Lin 8.10 Stacking Sequence FINAL	1:05
CMOFE Lin 8.11 Summary FINAL	:22