Aeronautical Engineering and Aerospace Engineering: A Learner-Centered Teaching Perspective in Higher Education

By Omid Gohardani, Amir S. Gohardani, Erin Dokter, and Kyla Macario

Teaching in the 21st century requires a modern teaching practice coherent with the evolutions of the Information Age. Interestingly, teaching practices have stretched beyond an art form and into the realm of science. Following these scientific trails, one can argue that one of the greatest challenges educators currently face is to maintain student interest in demanding subjects. From an educator's point of view, however, all subjects are equally demanding, as the adopted teaching practice for a particular subject matter equally needs to ensure that a student-learning experience is generated. Furthermore, an efficient teaching method for a particular subject is not necessarily equally efficient for another subject. Hence, the road map to professional teaching could essentially start from an empty page and develop into a detailed map that could prove to be valid for a specific teaching environment. In this article, particular facets of learner-centered education in higher education are highlighted with an emphasis on teaching subjects in aeronautical/aerospace engineering. Implementation of novel techniques in communicating ideas through illustrations, posters, and animations represents one of the interactive educational approaches of this specific era.

The Information Age constantly presents significant challenges to educators worldwide. Given the large portfolio of interactive means for communication—partially generated by advancements in technology—a classical teaching style of lecturing without any interactive elements could commonly be perceived as dreary within the contemporary learning and teaching environments. Adoption of a modern teaching style should therefore incorporate the gems of technology in favor of providing students with memorable learning experiences.

In this article, selected aspects of learner-centered education (LCE) teaching are reviewed with the purpose of highlighting a number of key features that portray a diverse set of methods used in learner-centered teaching (LCT). Following a short journey through selected glimpses of LCE and aerospace teaching education, a number of practical teaching methodologies are presented. These endeavors build on the advantages of the Information Age and introduce a novelty in capturing students' attention spans throughout the teaching practice phase and during the students' learning process.

Learner-centered education

In contrast to the traditional learning perception in a classroom setting, which primarily features a teacher or an educator as the main axis of information delivery, LCE focuses on the information flows brought to learners and serves as an application in further learning (Gunderman, Williamson, Frank, Heitkamp, & Kipfer, 2003). One of the main benefits of LCE is its emphasis on various teaching methods, which entails a transition of the role of the teacher from information provider to facilitator of the learning process (Blumberg, 2008).

Weimer (2002) identified five essential training areas to achieve LCT, including the function of content, the role of the instructor, the responsibility for learning, the processes and purposes of assessment, and the balance of power. In essence, the foundation of LCT rests on a solid basis consisting of knowledge and development of skills in conjunction with self-awareness of the learner. In this context, the role of the instructor is concentrated on student learning, allowing for the responsibility of learning to be placed on students. This shift of responsibility is essentially achieved by motivation of students and learning assessment as a part of the learning cycle (Blumberg, 2008). The applications of LCE have been realized in many scientific fields such as medical sciences (Chiang, Chapman, & Elder, 2010; Gunderman et al., 2003), computer science (Quintana, Krajcik, & Soloway, 2003) and psychology (McCombs,1993).

The topic of learner-centered education has been the focal point of many different investigations. This topic has been examined on the basis of its challenges (Cornelius & Gordon, 2008; Curry, Hershman, & Saizow, 1996; Meece, Herman, & McCombs, 2003; Sadler, 2012), implementation (Boyd, 2012; Gerstein et al., 2010; Schuhm, 2004; Schweisfurth, 2011; Thompson, 2013; Tudor, 1992; Wood, 2008), attitude change in students (Spencer, Phipps, & Alowayesh, 2012), effectiveness (Wang, Lee, Chen, & Wei, 2012), and the shift from teacher-centered education (Wolbrink & Burns, 2012). In this article, the practical approach for implementing LCE and LCT in aeronautical and aerospace engineering disciplines is underlined. Hence, an excursion through particular phases of the aerospace education domain is of further interest, followed by a few related case studies.

Selected glimpses of aerospace education

An increasing level of aeronautical and aerospace activities mirrors an unprecedented incentive to pursue new areas within these disciplines. In view of all the significant achievements within the aeronautical and aerospace engineering sectors, respectively, one of the challenges of educating new students for the future is to partially modernize the education programs so they reflect the needs of the future (Fletcher, 1997). Further, Fletcher and Page (1993) also recognized that the increasing focus on space exploration and use requires highly educated individuals with space engineering capabilities. For this purpose, a substantial technology transfer needs to take place from government and industry to academic institutions.

Exchange of ideas among different aerospace engineering institutions can be perceived as at least a limited knowledge transfer. Over the years, a considerable number of such collaborations have taken place (Dannenhoffer & Cottrell; 2005; Evans, Robinson, & Tate-Brown, 2009; Flammia et al., 1993; Koster et al., 2012; Olague, Leslie, Burton, & Knight, 2012; Raghunathan et al., 2005; Robinson, Evans, Tate, & Uri, 2008; Rosendhal, Sakimoto, Pertzborn, & Cooper, 2004; Schilling, 2012; Smith, Seigler, Smith, & Jacob, 2008; Tal, 2004; Thompson, 2003). In 1989 several MIT faculty members visited the Moscow Aviation Institute in an effort to promote student and faculty exchange and information (DeMeis, 1990). This effort marked one of the important steps for institutional collaborations between two of the leading countries in aerospace engineering. Collaborations of this kind have evolved to include an increasing number of countries making contributions to space technologies (Degtyarev et al., 2011). Emerging new topics in aerospace engineering are analyzed with new learning tools ranging from intelligent adaptive cyber-physical ecosystem for aerospace engineering education (Noor, 2011) to classical hands-on projects (Swartwout, 2011).

The role of LCT has become increasingly important with respect to the introduction of distance learning in aerospace engineering. Most aerospace professionals cannot afford to leave their current positions in order to meet the residency requirements for graduate studies in aerospace engineering. Salary loss due to an absence from the aerospace engineering field has to be balanced with the prospective future earnings as a result of achievements in higher education. Furthermore, it is well established that key personnel cannot afford to be absent from their positions for prolonged periods of time. In order to meet the demands for higher education in aerospace sciences and for the purpose of fulfilling their respective residency requirements, recognized institutions such as Columbia University and Michigan Technological University now offer doctoral degrees by distance learning (Jones & Klose, 2012). From this perspective, the prospects of pursuing higher education within aerospace sciences by means of distance-learning programs, and the subsequent shift from teacher-centered learning toward LCT is hence becoming more frequent with programs such as the one offered for master of science degrees within Aerospace Engineering at the University of Alabama (Jones & Klose, 2012).

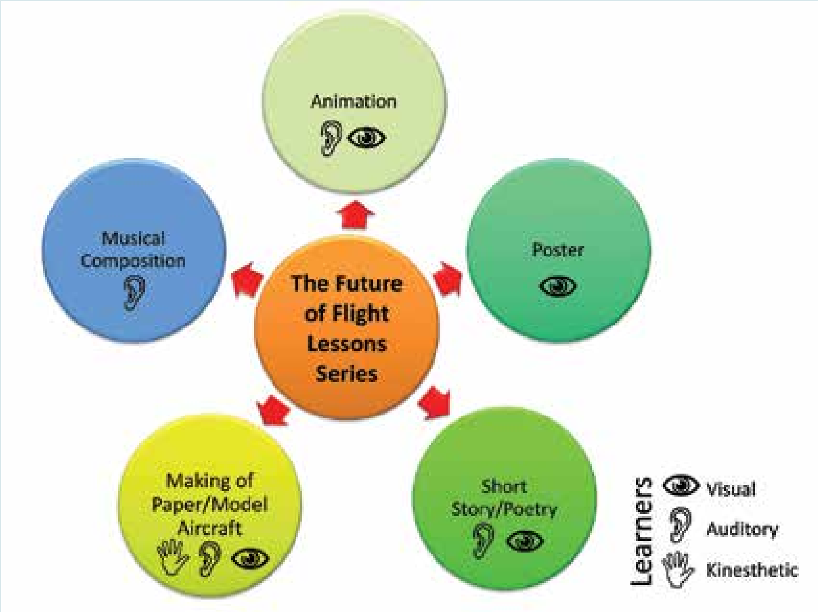
Methodology and methods of the study

A specific method that can be highly efficient in learner-centered approaches is the activation of the general senses. When such an approach is adopted, the focus should primarily be set on these three senses: sight, hearing, and touch. In essence, this methodology seeks to include at least one of the senses during each learning phase. The idea is to incorporate a mixture of these senses for different learning tasks, hence expanding the learning process to incorporate visual, auditory, and kinesthetic learners. Implementation of the aforementioned theory can be traced in an example that relates to a Future of Flight learning session. In this lecture series, the future of flight is examined by several means of educational tools that are representative of different layers for different learners, in accordance with the information in Figure 1.

Each of the components described in Figure 1 activate the interest of a distinct sense or a collective of senses. Exposure of learners to the broad spectra of learning consequently enables a more successful teaching process. The implemented methodology in this study makes use of various means in order to promote an LCE approach. Thus, the focus of this methodology is to consistently use different technological channels

FIGURE 1

The future of flight, explored by a musical composition, animation, short story, poster, and poetry.



in the teaching of subjects within the fields of aeronautical and aerospace engineering.

Case I: The Theory of Flight

Case I represents one case of capturing the interest of the learners in general aviation. This teaching approach was particularly aimed at the introduction and identification of four basic forces acting on an aircraft during flight with a partial goal of defining an *airfoil*. Given that the learners in the class only had general knowledge about aviation, the teaching level was tailored for a 100-level course.

During this teaching session, the outlined topics consisted of establishing a force balance on an aircraft during flight and defining and making an airfoil, followed up by an interactive quiz. The session targeted auditory learners, kinesthetic learners, and visual learners. Microsoft PowerPoint and ELMO Visual Presenter as technological instruments for presentation purposes were used, and the principal teaching efforts were primarily directed toward generating student interaction and brainstorming activities.

The analogy to fully comprehend a flight scenario was instigated by showcasing a video clip in which birds from a level flight position went in for landing. Through capitalizing on the learners' previous understanding of a simple scenario that revealed how a bird or an aircraft could maintain level flight, the force balance between the aircraft weight, lift, thrust, and drag was established. Another analogy was also given with regards to drag generation. The empirical experience of placing the palm slightly outside the window of a moving vehicle and feeling the force of the wind is a clear indication of the exerted drag force on the palm.

In these sessions, the enabling link resulting in an interaction between the educator and the students was partially denoted through the *minute reflection*. This concept permitted learner reflections about a series of questions that did not require any previous aeronautical knowledge and were aimed to revisit the inherent subconscious stored knowledge.

Interaction with students would often lead to a brainstorming session about the topic in question. This session was further followed by the instructor highlighting the correct assumptions made by the learners. In addition, there would also be a discussion about the reasoning behind the inaccuracy of certain assumptions. The emphasis in this framework was nonetheless always placed on learner engagement and in favor of stimulating unique experiences for the learners. Engagement of both visual and auditory learners was simply achieved through the introduction of interactive quizzes. In the aforementioned quizzes, musical compositions and audio clips in conjunction with animated graphics would expose the learners to a session in which the crucial topics of the subject matter would be highlighted. In these quiz sessions, the learners rapidly established a feel for what they would expect, and hence their engagement level in the topic was enhanced considerably. To incorporate the kinesthetic learners in this teaching series, the definition of an airfoil was easily explained by folding of a blank paper sheet with the two ends of the paper placed on top of another and the flat hollow region in between them representing the airfoil. The sheet of paper further facilitated the explanation of why an extrusion of an airfoil could represent a wing section. Different aircraft rotations were further explained through animations, the making of paper airplanes, and analogies with bird flight. In conclusion, on the basis of the postassessment reviews of these activities, learners that participated in these series of lectures felt that they were encouraged in critical thinking and exposed to a learner-centered approach in the basics of flight.

Case II: The Future of Flight

In contrast to Case I, which was aimed more at a classroom session, the Future of Flight lecture series was essentially aimed at a larger audience beyond a classroom setting. Hence, the different building blocks in these series consisted of teaching measures that would result in an overview of the topic without the presence of a lecturer or a narrator.

A learning session was implemented with the purpose of exploring the future of flight. In particular, the implemented methods in this study consisted of the following:

- an interactive presentation, using both audio and video;
- a static presentation, implementing simplified graphics; and
- an animated presentation, using motion picture design in education.

In the interactive session, the class became a center stage for the educator who interacted with the learners on a frequent basis. The challenges associated with such an approach included instigating the interaction with the learners. A simple measure for this initial interaction was to include a quiz-type session in PowerPoint, where each question was based on the initial student knowledge about the subject. Thus, the session first and foremost enabled the educator to assess the knowledge level of the learners. Following this trail of thought, dual benefits were gained for both the educator and the learners. From the learners' perspective, the self-confidence level is built simply as they systematically recognized their undiscovered strengths and the wells of their previous knowledge. From the vantage point of the educator, the interactive quiz is a natural opening remark and yields to an instant involvement of the learners. The role of audio clips in this context cannot be overemphasized. In essence, learners are not expecting any audio output during a PowerPoint presentation. Hence, coordinated audio clips that, for instance, will last during the allocated time slot for answering each question can contribute to several positive factors. Initially, these audio clips instantly promote a level of suspense. In this setting, the learner will be given the opportunity to provide the educator with his or her answer during the duration of the audio clip. In addition, usage of audio clips adds another level of interaction with the learner where the audio length, its character, and frequency of usage can be adapted to a particular task of interest in the presentation.

Second, for static presentation purposes, a poster that features simplified graphics is considered. We believe that using a colorful poster such as the one shown in Figure 2 is more likely to capture the attention of the learners in comparison to a conventional scientific poster with plain graphics. The challenge herein is placed in having a clear and distinct means of communication with the learner.

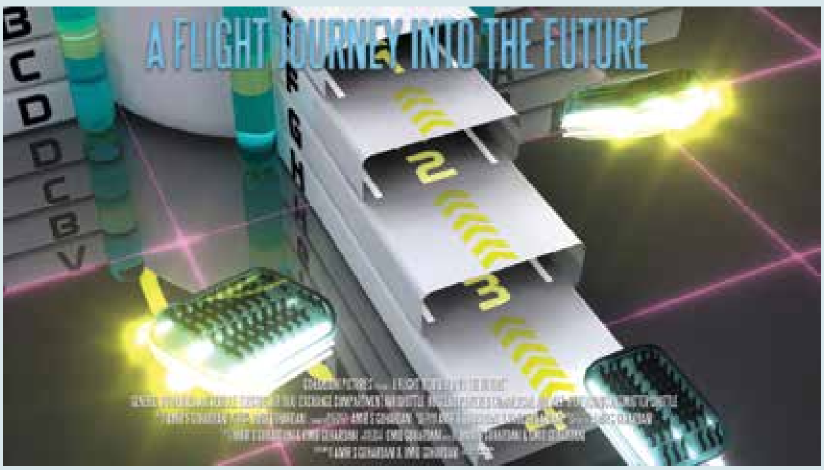
This objective can for instance become actualized by a timeline, as shown in Figure 3, which further reveals the development of different aerospace design concepts. The timeline serves a twofold purpose. First, it depicts a distinct categorization between different conceptual designs. This in itself provides the learner with an overview of diverse categories. Second, the piece of information within each time period is conveyed by means of text and illustrations, respectively.

A motion picture or animation activates different senses of the learners simultaneously and could spark their curiosity according to the interactive means of the Information Age. A snapshot of an animation sequence is shown in Figure 4, and the animation clip is also included as an attachment to this article.

The notion of viewing a set of images in motion can sometimes lead to an unaware learning process. This method—if tailored to specific teaching subjects—can represent one of the most interesting aspects of a teaching process and typically draws the attention of the majority of the learners because of its unusual feed of information. The medium for teaching

FIGURE 2

A motion picture poster for the lecture series, A Flight Journey into the Future. The design of the poster is intended to captivate the interest of the learners and to instigate their awareness about the vertical compartment airport—the ultimate solution to airport congestion issues in the future. Source: Conceptual design by Dr. Omid Gohardani and Dr. Amir S. Gohardani, ©2011. All rights reserved.



with a motion picture can consist of both audio and video. Such a teaching method, however, could prove to be time demanding and requires that the educator makes long-term plans before introducing a specific lecture series.

Data collection and learning assessment

The first case study was aimed at identification of the basic forces acting on an aircraft during flight. The learning assessment method at the end of each classroom session was actualized by open discussions with the students and through a quiz.

Results

Two different case studies were carried out for topics related to aeronautical and aerospace engineering. The first topic was titled The Theory of Flight and the second topic was titled The Future of Flight, respectively. The learners in the class were a diverse group of individuals with a general knowledge about aviation. These lecture series were further tailored for a 100-level class. Hence, the educators made use of the existing knowledge of the learners and implemented different interactive methods to activate a mixture of senses. Through up-to-date and interactive presentation approaches, the learning process was expanded to incorporate visual, auditory, and kinesthetic learners, as highlighted in LCT and LCE. The learning objective results based on interactive quizzes are shown in Figure 5.

Conclusions

The LCE approaches undertaken in this study have exhibited that it is possible to effectively implement LCT in teaching endeavors within aeronautical and aerospace engineering. It is interesting that the results from this study also indicate that despite the intricate nature of the aforementioned disciplines, explanation of ideas could potentially become easier through interactive media. The findings of this study further point to the fact that different teaching practices can increase the diversity in the learning process and include learners from different learning styles. In essence, adaptation of information sharing via different forums on the internet can further remove any restrictions imposed by spatial con-

FIGURE 3

A timeline for prospective aerospace vehicles proposed for operation between the years 2020 and 2100. Each concept is suggested according to the prospect of the technology maturity level for the proposed year. From left to right, the following conceptual aerospace vehicles are suggested: Generic Unmanned Air Vehicle (GUAV), Exchange Compartment Air Carrier (ECAC), Electric Air Taxi (EAT), Nuclear Powered Commercial Airliner (NPCA), and Hypersonic Antimatter Shuttle (HAS). Source: Conceptual design and rendering by Dr. Omid Gohardani and Dr. Amir S. Gohardani, ©2011. All rights reserved.

straints in a classroom and moreover allow the learners to participate in the learning process at arbitrary instants, outside the classroom setting. Conclusively, it can be stated that state-of-the-art technologies should be used in teaching of advanced topics such as aerospace sciences and for the purpose of incorporating effective teaching methods. The role of animations or motion pictures will become prevalent in the teaching of advanced scientific topics, and these means of visualizations can potentially become extremely pronounced in future learning and teaching processes. Information technology bears the advantage of facilitating the shift from a teacher-centered approach to a learner-centered approach and equally pave the way for the transfer of knowledge across different subject areas or disciplines and, most important, between the educators and the learners. ■

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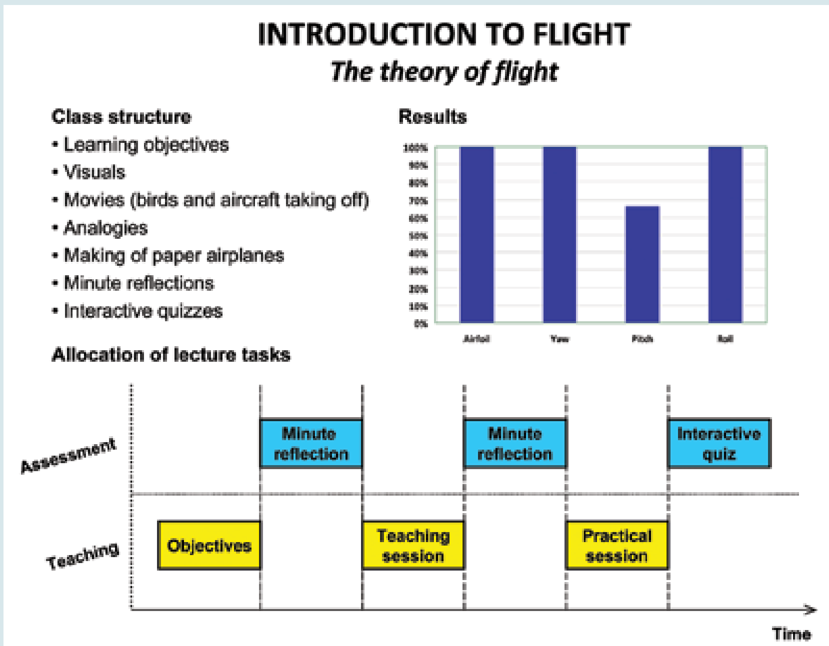
FIGURE 4

A conceptual airport suggestion for the future. The vertical compartment airport enables simultaneous landings and takeoffs of at least eight aerospace vehicles, hence, minimizing airport congestion to a level where it is virtually nonexistent. Source: Conceptual design by Dr. Omid Gohardani and Dr. Amir S. Gohardani, ©2011. All rights reserved.

FIGURE 5

The class structure, allocations of lecture tasks, and percentage of students who learned the class objectives related to introduction to flight.



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