Incorporating Entrepreneurial Minded Learning into an Undergraduate Dynamics Course

by

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Abstract

Inspired by the KEEN Foundation's mission, results are shared from incorporating entrepreneurial minded learning (EML) into an undergraduate Dynamics course within a mechanical engineering program. A "KEEN" team project was given to the students in which they were asked to pretend that they were members of a startup company that would design, build, test, market, and sell a product with some dynamics content to it. As part of the exercise, the 20 teams worked on idea generation, concept development and identification of required activities, in addition to writing a draft Business Plan. Product ideas varied across different economic sectors including power generation, sports technology, transportation, food and beverage technology, and health care. Grading of the resulting reports incorporated factors such as: (1) was there sufficient dynamics content, (2) could it work, (3) was is innovative, (4) were the students familiar with the technology, and (5) would J (January)-Term and spring semester and modest funding (if needed) significantly advance the idea? The top 3 teams made more progress during J-Term and spring semester, with each team fabricating a prototype device. Students were also asked to answer a short survey about the KEEN project and the results were generally positive, such as being more interested in dynamics due to participating in the KEEN project.

1. Introduction

KEEN (Kern Entrepreneurship in Engineering Network [1]) was created to instill an entrepreneurial mindset into engineering education so that future engineers will better appreciate and embrace business aspects of engineering, specifically innovation and entrepreneurship. It was started by the Robert Kern Family in 2005 and today approximately 28 private engineering universities are members within the network, including the University of St. Thomas (as of 2016). Despite being a little over a decade old, KEEN already possesses a rich history as detailed in works such as in Fry et al. [2]. Activities of KEEN member organizations and individual faculty members include semi-annual conferences for university members, adding entrepreneurial content to engineering curricula and courses, and development, refinement, evolution, and articulation of "KEEN outcomes," somewhat analogous to ABET outcomes. Attributes of an engineer with an entrepreneurial mindset include a base of technical fundamentals, business acumen, and customer awareness, all of which attempt to support societal values. In KEEN-related literature these attributes are often shown geometrically in the form of a now iconic tetrahedron with societal values representing the top vertex and the other 3 residing on the base triangle. More recently, curiosity, connections, and creating value (the 3 "Cs") have been used to describe the entrepreneurial mindset (e.g. Erdil [3]).

Different institutions have employed different approaches to infusing engineering curricula and courses with entrepreneurship content, including a systemic approach, focusing on freshman Introduction to Engineering courses, and specific upper-level core engineering courses. Below, we summarize results reported in the literature from implementation of each of these approaches. Mallory et al. [4] report implementation of a systemic approach whereby EML modules are brought into two second-year engineering courses required of all engineering students, i.e. Statics and Probability and Statistics. Erdil et al. [3] have developed, or have plans to develop, 18 different e-learning modules that will be integrated into engineering courses spanning all four years across all engineering and computer science disciplines.

Within the discipline of mechanics-related engineering, such as mechanical engineering (ME), several universities have implemented aspects of EML into their curriculum and courses. Schar et al. [5] at Stanford University have embedded EML into a course that emphasizes solid mechanics and additionally they were able to survey the students pre- and post-EML to determine, among other things, if the EML exercise diminished the knowledge of core engineering concepts – it did not. At Kettering University, students taking automotive related courses were given EML opportunities such as designing a powertrain or improving engine performance (Davis [6]), possibly in connection to the FSAE race car design contest. Student reviews weren't uniformly positive as some students felt that this type of learning experience is better suited for an internship, vs. a traditional course.

2. EML Project in Dynamics

The University of St. Thomas recently joined the KEEN network and the work presented below reflects its first foray into use of EML in a Dynamics course taken by undergraduate ME students. Dynamics (ENGR 322) is a classic ME course typically taken by juniors, although sophomores and seniors with the proper prerequisites may take it as well. It has both a lecture and a lab to it that collectively, offer broad coverage, with the lecture focusing largely on applications of mathematical and physics-based theories to engineering problems and the lab getting into simulation software (e.g. MATLAB and Simulink), instrumentation and measurement (e.g. LabVIEW), and several design-build-test projects. Historically, what has not been a part of Dynamics, is anything to do with business, such as entrepreneurship. Through a grant from the KEEN Foundation [1], that opportunity presented itself, and the thought was to experiment with use of an entrepreneurship team project. Would it improve student's interest in the topic of dynamics? Would ME students become more interested in entrepreneurship aspects of their discipline? Below, the details of how the project was implemented within the course are described, from the project handout, related instruction, meetings with students, related feedback presented to the class, student reports, to the results of continuation efforts during J-Term and spring semester by the top 3 teams.

2.1 KEEN Entrepreneurial Minded Learning Dynamics Project Handout

A handout was given to the students that describes the project:

> **Project Description:** This project focuses on introducing an element of Entrepreneurial Minded Learning (EML) into the undergraduate Dynamics course (ENGR 322). For reference material, please read the following links or documents:

- http://www.kffdn.org/about/
- KEEN "white paper"
- Business Plan template [7]

in addition to other related material that you can find on the internet. To get even more excited about the topic of dynamics, especially the practical societal and inventive aspects, the thought is to bring in a business perspective which has never been done before, more specifically focused on entrepreneurial aspects. I envision 3 activities spread out over the latter portion of the semester in which student teams (3 students per team nominal) work on the development of a product idea that possesses a significant need for dynamics content. In the process the students will work on the following graded activities, each of which will be discussed in a series of short informative lectures:

Idea Generation

- At least 4 ideas need to be presented in a very organized fashion, each with a ½ page description and a neat cartoonish figure (hand drawn and scanned in is okay) that depicts the envisioned device and its usage. It should be something for which a quality prototype could be developed in a year or two by talented engineering students and a few supporting personnel. It must solve a perceived societal need and be something that could be a product that can be sold to consumers. Allocate 1 page total per concept.

Concept Development and Identification of Required Activities

- The above ideas need to be scrutinized, traded off (e.g. using a chart), and a preferred concept selected.
- Development activities need to be identified, each with an overview presented, e.g. detailed design of X, simulation of Y, manufacturing of Z module, etc. The different types of personnel required can be identified as well.
- Identification and description of significant dynamics content, be it related to: (1) dynamic modeling and simulation, (2) instrumentation, (3) design-build-test of the device, or (4) device usage. For example, you don't need to solve any differential equations, but rather recognize the need for performing certain types of dynamics analysis and setting up certain types of equations that need to be solved.

Business Plan (attempt at)

The team can use a free template available from the internet, such as one used by the University of Michigan. Complete it to the extent possible. Again, the perspective is that the team is a small start-up company. You can even come up with a name for your company!

Deliverables: Soft and hardcopies of report documenting the above 3 activities in 1 WORD file.

Grading: A report containing documentation of all of the above activities will be graded by the instructor and the top 3 teams will be honored in class and asked to say a few words about their project idea. To improve the quality of the final reports there will be a short review meeting scheduled with each of the student teams and comments offered on their ideas and documented work. The top 3 teams will also be eligible (their option) to compete for $500 that can be used in J-Term and spring semester to further advance their design.

2.2 Related Instruction

Several short lectures were given on the general topic of EML along with providing background information on KEEN. Additionally, focus was on creativity and design, entrepreneurship generally, business plans, and feedback to the entire class based on partial progress.

Creativity and Design: Critical to getting started on the project is being able to generate some good ideas, which based on my observation, can be difficult for some students, or at least make

them feel uncomfortable. One fun class exercise that was used to help students be able to generate ideas was based on improv comedy, whereby a series of categories (3 or 4 being typical), or themes are suggested by the class and then collectively we try to think of an idea that fits within all of the categories. Of course, few of us are as good at improv as Wayne Brady, but this exercise served as a quick demonstration of how easy it is to start generating ideas. Lastly, it's also worth mentioning that almost all of the students, certainly if they matriculated at St. Thomas as freshman, have taken both *Introduction to Engineering* (ENGR 150) and *Introduction to Graphics and Design* (ENGR 171) where they were exposed to a design experience and many of them were taking other design related courses such as *Machine Design and Synthesis* (ENGR 320) and *Engineering Design Clinic I-II* (ENGR 480-1) which helped with the project.

Entrepreneurship Instruction: The MIT set of OpenCourseWare courses [8] offer short lectures on various entrepreneurial topics, some of which were shared with the students as a means of introducing the topic and providing a source of inspiration for their work (e.g. from Bill Aulet). An additional source of entrepreneurial inspiration shared with the students pertained to a recent story from the ME Magazine [9] in which an undergraduate student who was also an athlete that kept experiencing concussions in their sport, invented a product that measures and reports the G-impact of each collision. This student now has a successful start-up company and it showed the Dynamics students what kind of success is possible.

Business Plan: With the lead product concept selected, a template Business Plan from the internet from the US Small Business Administration Small Business Training Network ([7], also referenced by the University of Michigan) was given to the students to use as a guide to follow. Viewed as an outline of content, it contained core sections on:

- Executive Summary
- Business Description and Vision
- Definition of the Market
- Description of Products and Services
- Organization and Management
- Marketing and Sales Strategy
- Financial Management

Students easily generated responses to be able to fill in a Business Plan template. How realistic, complete, and accurate the responses were is another topic of discussion, but at least they were going through the important exercise of pretending to create a start-up company that would sell an engineered product with a dynamics theme to it. Some of the teams had fun with this aspect of the project and even injected some elaborate fictional content, such as regarding financials or the backgrounds of the co-founders. That said, in quite a number of cases, without any direct coaching from the instructor, student teams mentioned a number of ethical company principles such as: (1) honesty, (2) integrity, (3) quality, (4) safety, (5) respect, (6) loyalty, and (7) reliability, which was encouraging to see. Financial matters were all over the place, largely made up of course, but in some cases they made a legitimate attempt to establish a realistic price point and manufacturing unit costs.

To improve the learning experience for the students and overall quality of the student work, each team was required to meet with the instructor outside of class to discuss their progress and receive

suggestions for improvement. Additionally, after meeting with all of the teams, common problems were noticed and some KEEN advice was given to the entire class, including:

- A reminder that the project must have a "Dynamics" theme or emphasis to it
- Make some kind of effort to see if your idea is truly new, such as using Google or the USPTO (United States Patent and Trademark Office)
- Mention what inspired you to come up with your best idea

Generally speaking, the vast majority of the students were receptive to the feedback and made some effort to further improve their projects.

3. Student Projects

In a class of 56 students, there were a total of 20 self-selected teams and a sample of project ideas are described in Table 1 with many visually depicted in Table 2 where a CAD image (SolidWorks) is shown. The project themes varied, although there were some common ones, like power generation (4 projects), sports technology (3), transportation (3), food and beverage technology (3), and health care (2). Inspiration for their ideas varied, some originating from personal experiences or those of close relatives and friends, and in other cases more altruistic or societal needs were the source.

Table 1 Sample of Project Ideas, Descriptions, and Inspiration

Ideas	Practical Description	Inspiration
Grade Saver	Snowplow blade height servo system	Talking with snowplow operators from rural areas of northern Minnesota
Safe Lite	Bike light intensity (i.e. frequency) varies with acceleration or deceleration	Interest in cycling and safety at night
Dynamic Training Wheels	By laterally shifting a mass in a controlled manner a bicycle's vertical posture is maintained	Interest in supporting youth cycling and training
Wave Impact Power Generation	Electrical energy is extracted from waves crashing on the shore using piezoelectric transducers	A concern for the ever-changing and sensitive environment of the earth and reduction of the effects of fossil fuel dependence
Door Piston – Emergency Sign Power Assist	Mechanical energy from a moving door is used to power a door-mounted Emergency Sign	Interest in generating sustainable energy in a non-traditional manner
Neva Spillz	Inertially stabilized gimbaled platform that prevents beverages from spilling	Spilling coffee in a luxury car
Traction Enhancing Snow Tire	Tire with actuatable traction strip containing spikes	Driving in Minnesota winters
Motion-Tracking Camera	Police camera on 2 or 3 axis platform that can track a fast moving target such as a fleeing suspect	Public safety and technology support of law enforcement to make a police officer's day safer
GlowyMat	Pressure sensitive gymnastic floor mat that glows in proximity of where pressure is applied	Watching Floor Exercise gymnastics at the Summer Olympics
Automatic Fruit Peeler	Motor-driven multi-fruit peeler	Increasing productivity within the food service industry
Water Bottle	Straw with an integrated flow meter embedded in it that measures how much beverage fluid is consumed	Accurate measurement of human water consumption, such as from a

		common water bottle that may have ice and be refilled multiple times
Natural Notes	A vision system observes how a person's hand moves while writing and then infers what was written	Tedium of student note taking
Bluetooth Controlled Golf Ball Guidance	A golf ball is endowed with its own propulsion and inertia guidance system that permits it to move along a desired trajectory, regardless of how the golfer struck the ball	Desire to shoot a lower golf score and interest in golf technology

Table 2 Sample of Visual Characterization of Different Project Ideas (SolidWorks)

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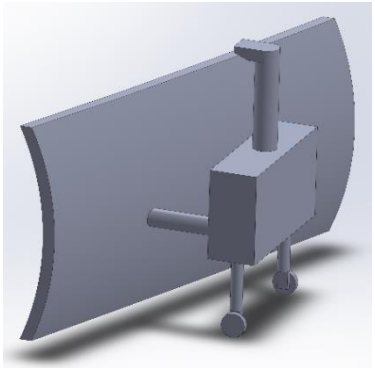
<td> 
Grade Saver</td>
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Safe Lite</td>
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Dynamic Training Wheels</td>
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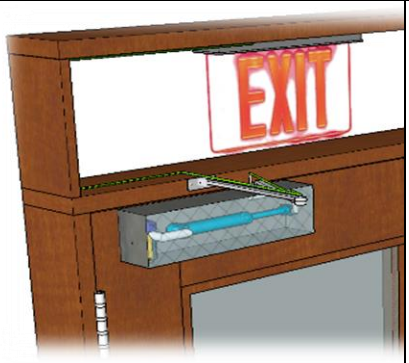
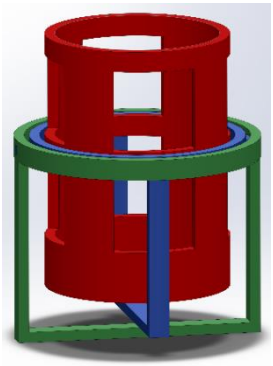
<td> 
Wave Impact Power Generation</td>
<td> 

Door Piston – Emergency Sign Power Assist</td>
<td> 
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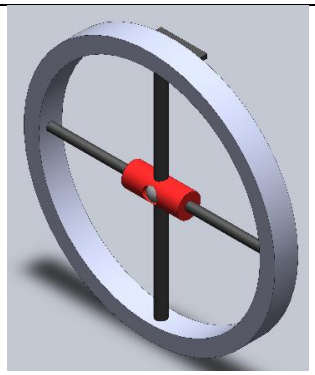
Traction Enhancing Snow Tire</td>
<td> 
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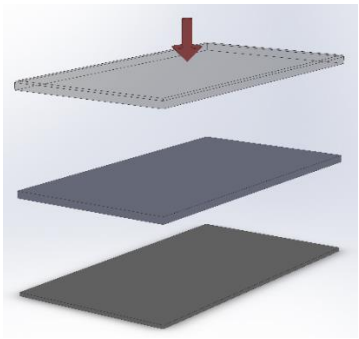
<td> 
GlowyMat</td>
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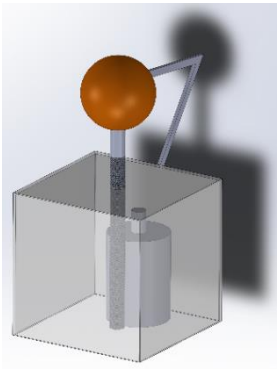
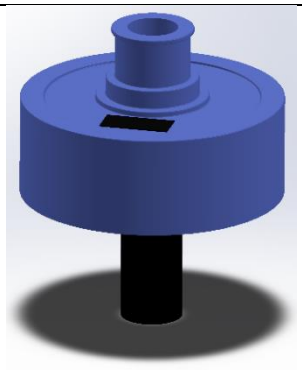
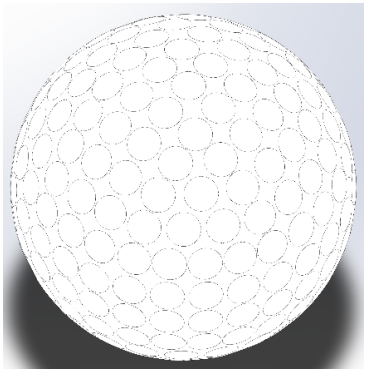
 **Automatic Fruit Peeler**	 **Water Bottle**	 **Bluetooth Controlled Golf Ball Guidance**

4. Evaluation of Student Projects

Several different practical criteria were used to evaluate the quality of the work submitted by the student teams, including:

- Was there sufficient dynamics content?
- Could it work?
- Innovative?
- Technology familiarization (by students)?
- Would J-Term and spring semester and $500 significantly advance the idea?

Table 3 presents the results.

Table 3 Evaluation of KEEN Project Ideas

	Dynamics Content (High-3, Med-2, Low-1)	Could it work? (Yes-1, No-0)	Innovative? (Yes-2, Maybe-1, No-0)	Technology Familiarization (Yes-2, Not sure-1, No-0)	J-Term and spring semester + $500 make progress? (Yes-2, Maybe-1, No-0)	Total (10 max)
Grade Saver	3	1	2	2	2	**10**
Safe Lite	2	1	2	2	2	**9**
Gun Recoil Reduction System	3	1	1	2	2	**9**
Dynamic Training Wheels	3	1	1	2	1	**8**
Wave Impact Power Generation	3	1	2	1	1	**8**
Door Piston – Emergency Sign Power Assist	2	1	2	1	1	**7**
Engine Gyroscope	2	1	2	1	1	**7**
Adjustashelf	1	1	1	2	2	**7**
Neva Spillz	2	1	1	1	1	**6**
Traction Enhancing Snow Tire	2	1	2	1	0	**6**
Motion-Tracking Camera	3	1	2	0	0	**6**
GlowyMat	1	1	2	1	1	**6**
Automatic Fruit Peeler	1	1	0	2	2	**6**

Water Bottle	2	1	1	0	2	**6**
Natural Notes	2	1	2	0	0	**5**
Bluetooth controlled golf ball guidance	3	0	2	0	0	**5**
Prosthetic Leg	2	1	0	0	0	**3**
Diaper Changer	2	0	1	0	0	**3**
Sinking for Fuel	2	0	0	1	0	**3**
Hydro-Differentiation Generator	2	0	0	1	0	**3**

5. Continuation Effort Extended to Top 3 Teams

The top 3 teams (shaded rows in Table 3) were interviewed during finals week and based on some clever and efficient prototyping ideas, it was felt that $500 (total) would be enough to help all of the teams advance their idea during J-Term and spring semester. Each of the teams were excited about receiving some acknowledgement of their work to date and wanted to make a prototype. Below we present the results of one of these team's efforts during J-Term and spring semester through a perspective of curiosity, connections, and creating value.

5.2 Safe Lite

The Safe Lite concept (see Figs. 1 and 2) represents an attempt to bring motion-induced intelligence to the bicycling safety world, especially at night. Motion, such as braking or acceleration is sensed with an accelerometer and an appropriate ergonomic change in the LED display occurs, such as varying the frequency of the flashing display in the case of braking. This capability is also bundled with turn signal capability (i.e. left/right) which can conveniently use the same hardware. Limited testing was performed with a rider on an actual bike by one of the team members and it provided a useful mechanism for adjusting the acceleration thresholding and related processing. It is worth mentioning that similar technology exists for bike helmets already, but this concept is different in that hardware is mounted directly to the bike which has certain advantages, such as insensitivity to the rider's own motion.

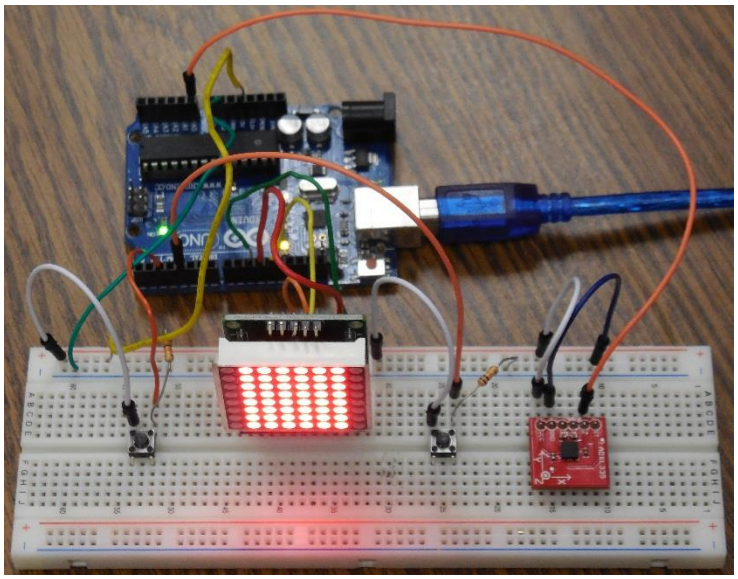


Fig. 1 Bench-testing of prototype Safe Lite using an Arduino, accelerometer (Analog Devices ADXL335), and digital display.

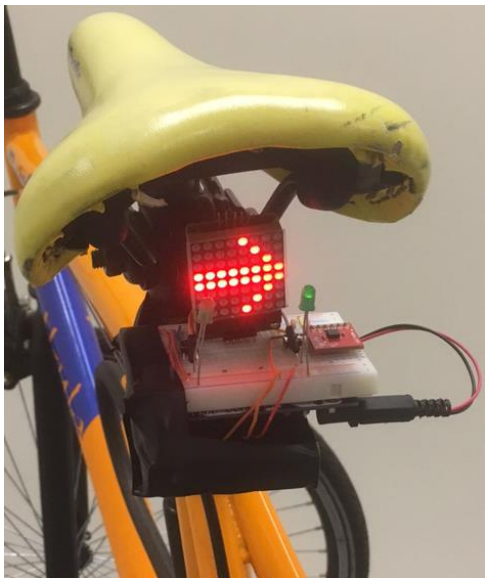


Fig. 2 Prototype Safe Lite mounted to a bicycle.

6. Student's Assessment of KEEN Project

On the last day of class and just prior to the announcement of the top 3 KEEN projects, a short survey was given to the entire class to assess their perception of the KEEN project, as provided in Table 4.

Table 4 KEEN Student Survey

	Significantly Less Interested -- 1	Less Interested -- 2	Indifference -- 3	More Interested -- 4	Significantly More Interested -- 5
Q1: Interest level in dynamics was enhanced?					
Q2: Interest level in entrepreneurship was enhanced?					

Did you previously know what a Business Plan was? Yes No

Results from 52 responses were compiled. An average of 3.34 (out of 5) for Q1 indicated slightly more interest in dynamics due to the KEEN Project. For Q2, the average was 3.89 which showed more interest in entrepreneurial aspects of mechanical engineering. As for the Business Plan, about 35% of the students had not previously heard of it. Generally, the comments received about the project were positive. Some of the more common suggestions for improvement were:

- Start the project sooner, allowing more time for completion
- Consider narrowing the product focus, such as to a specific industry or theme
- It would have been fun to make an actual prototype

In summary, overall the students responded positively to use of the KEEN Project and they offered some construction criticism.

7. Conclusions

From this effort a number of conclusions can be drawn, specifically:

- Since most of the students end up working in industry, it was rewarding to see students adopt an entrepreneurial mindset in the context of dynamics. Overall, the student survey suggests that student's interest in dynamics was positively impacted.
- All students became aware of what a Business Plan is and based on their narratives, some of them had fun pretending that they had created a start-up company.
- Most students appreciated the contest aspect as it acknowledged the work done and the possibility of some financial support during J-Term and spring semester to further advance their idea.
- A few students were uncomfortable with the open-ended nature of the project; others thrived. Either way, the next time the students encounter an entrepreneurial opportunity, common in follow-on coursework and industry, they should feel more prepared.
- Based on the results so far, the instructor will seriously consider incorporating EML into some future offerings of the Dynamics course. Minor refinements, such as those suggested by the students, can be easily incorporated.

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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