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The Teaching-learning Process of Lean Concepts

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ABSTRACT

Lean manufacturing methodology and its underlying philosophical principles is today a powerful and systematic approach in running competitive business. Industrial Engineering curricula and students in IE programs must adopt and master this powerful approach for their future professional practice. In order to make an effective University teaching-learning process, the "active learning" practice has emerged as an effective approach. Today, there are in the market place, effective dynamic workshops and didactic material like simulators for involving students in that teaching-learning process. Their use has been successfully proved. Nevertheless, there is a hided powerful factor that catapults a positive effect in the learning process when students are involved in the early steps of this "active practice". It involves aspects such as developing the practice idea, selecting the material or prototype and organizing teams by themselves. This article reports one of these project experiences where students of an Industrial Engineering curriculum, design and build their own experimental practice through a lean project. The project was used to illustrate lean concepts and tools such as VSM, process standardization, one peace flow, JIT, kanban, supermarket, line balance, line efficiency, and so on. During the project development all students showed great involvement, high productivity, and contagious enthusiasm.

Keywords
Lean Manufacturing, learning lean concepts, lean projects, lean tools.

1. INTRODUCTION

Lean manufacturing methodology and its underlying philosophical principles is today a powerful and systematic approach in running competitive business. [1-4]. The Industrial Engineering curricula and students in IE programs must adopt and master this powerful approach for their future professional practice. An active learning strategy is an effective way to learn Lean Manufacturing. "Active Learning" is a focuses learning pedagogical method which engages students thinking using real-life and imaginary situations. Active learning comprises techniques such as: problem-based learning, projects oriented learning, The Case Method [5, 6]. To develop this learning approach, today, there are in the market place, effective dynamic workshops and didactic material like simulators for involving students in that teaching-learning process. Their use has been successfully proved. Nevertheless, there is a hided powerful factor that catapults a positive effect in the learning process when students are involved in designing the learning activity. This article reports one of these project experiences where students of an Industrial Engineering curriculum, design and build their own experimental practice through a lean project; i.e. based in the Project Oriented Learning approach.

2. THE PROJECT LEARNING PRINCIPLES AND METHODOLOGY

Project-based learning (PBL) is a model that organizes learning around projects. Projects are complex tasks, based on challenging questions or problems, assigned to students who must be involved in designing, use problem-solving, and make decision, or investigative activities; in order to work relatively Autonomous. At the end, they must end up with realistic and valuable results [7, 8]. The project by itself must include authentic content, explicit educational goals and the teacher roll is facilitation but not direction in the involved process [9]. Other characteristics of the project base learning are: cooperative learning, reflection, and incorporation of adult skills [10, 11]. The successful use of this PBL approach in the engineering context has also been reported [12, 13].

A guide for designing and implementing the methodology content the following steps:

1. Before of the planning of the project. The teacher should consider items such as: the duration of the project, complexity, available technology, the scope which this will have and the support that students will receive.
2. Definition of goals. The teacher must clearly define goals and objectives intended that students achieve.
3. Definition of expected results in students. The teacher should identify specific objectives and learning outcomes of the students.
4. Identification of question Guide. The teacher must submit to students a question guide that allows them to give coherence to the little or no structure of problems or activities that will face each other to carry out their projects.
5. Identification of sub-questions and potential activities. Define what they should do the students in search of answers.
6. Definition of expected products. The teacher should determine what type of products expected of students, can be buildings, presentations or exhibitions carried out during the project.
7. Definition of learning activities. These activities should take students to deepen the knowledge. Some of the activities that teachers can suggest, to enable students to perform during your projects are: research, planning, consultation, demonstrations, troubleshooting, etc.
8. Definition of the kind of institutional support. The teacher should define the type of support that students will receive to guide their learning; it can be: presenting them some readings, with feedback, instruction, etc.
9. Preparing the environment. The teacher should try to promote optimal working conditions for its students.
10. Identification of resources. Teachers should identify the type of resources used and whether these will be provided as part of the project or the students must look for them.
11. Determination of the evaluation. To determine how the student assessment will be conducted, the teacher should use different elements to determine if students have achieved the objectives of the project. The evaluation can be carried through the development of the project, as well as on the basis of the product obtained.

3. PROJECT DESCRIPTION

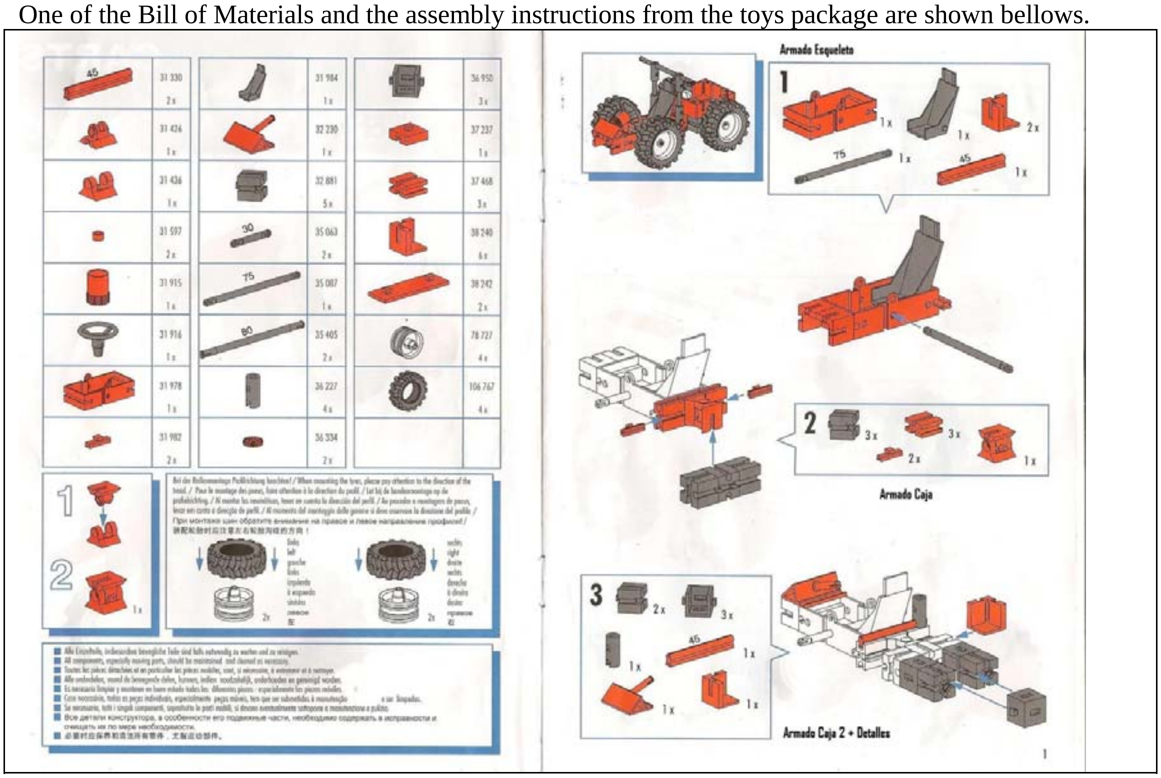
This action project base learning was administered on some 30 students enrolled in the Lean Manufacturing course at the Engineering Department of the University of Monterey (México) in the Industrial Engineering academic curricula. The learning content for the Lean Manufacturing (IN3310)) course includes 40 hours of lectures. Among the full activities program there is a project base activity related with the Value Stream Flow analysis. The project is used to illustrate the following lean concepts and tools: VSM, Process standardization, cell production, FIFO, One peace flow, JIT, Kanban, Supermarket, Capacity process table, Work combination table, Line balance, Line efficiency, Lead time, Peace maker, Value and No-value Mapping, Work content, and Quality at the source. Planning the project there is entirely freedom for selecting and developing the process to study the technical aspects listed above; the only restriction is to use a commercial assemble toy car from Fischer technik brand. The team is build with five students freely grouped by their personal preferences. The goals and related instructions as well as the evaluation criteria, was discussed ant content in the following project instructions and evaluation rubric:

- <u>Project team</u>: Integrate teams of five students using your personal affinity for your classmates.
- <u>Project name</u>: Assembly of trucks Lego Fischer technik
- <u>Project duration</u>: Two weeks, including 6 hours in classroom for professor consulting and as many as necessary out off class.
- <u>Project Goal:</u> Achieve an efficiency of the production line over the 90%
- <u>Technical analysis content</u>: Current Value Stream Map, Future Value Stream Map, line balance, line efficiency, one peace flow improvements, Pull production, standardization of operations

- Detonating question: what is the best operating arrangement of the flow of the production line to maximize their performance?
- Operation instructions: a) purchase the kit of parts of the vehicle to analyze brand Fischer technik. b) read instructions of Assembly and design a process including one workstation for each stage of the assembly instruction manual (current layout graph); c) use the Planning Capacity Table to calculate the cycle times for each station; d) identify bottleneck; e) Draw the VSM considering one 8 hours shift production for projecting inventories; discretionarily assign the rest of the information necessary for characterizing the process performance; f) Identify areas for specify kaizen for improvements; g) calculate the process capacity; h) graph the current performance and include basic performance indices; h) establish the future value stream flow; i) balance the line and promote continuous flow; j) calculate the new process performance.
- Project deliverables: written technical report: a) Introduction; b) Description of the problem; c) Development of analysis and design of the project (which integrates formats: current VSM, future VSM, Planning document, Process capacity table, Standard work combination table, Standard work layout, Work instruction sheet. c) draw the findings and conclusions; bibliographic references using APA formatting style and; include testimonial personal pictures when working
- Project evaluation: (a) contents of the report (70%), (b) format of the report (10%), (c) order and cleanliness (10%), (d) personal conclusions (10%).

4. PROJECT DEVELOPMENT

One of the Bill of Materials and the assembly instructions from the toys package are shown bellows.



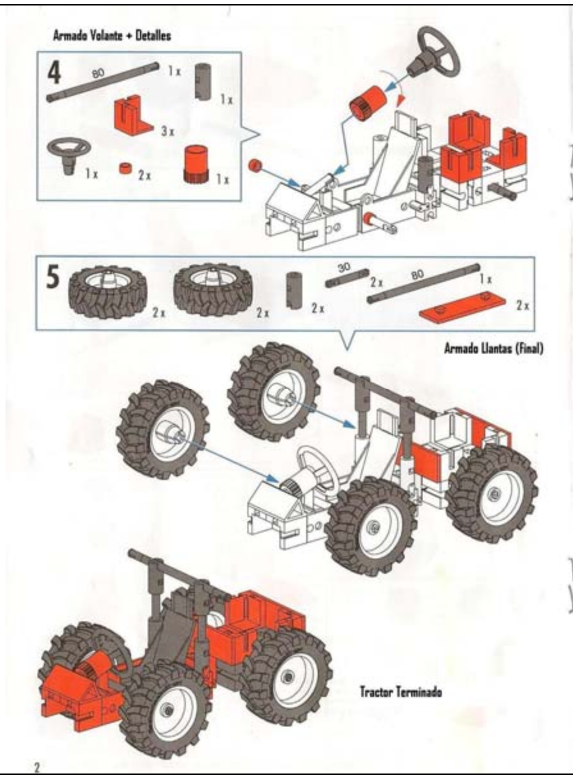


Figure 1. Example of Bill of materials and assemble instructions of the car

The project team was freedom to organize the assembly process and the measurements to determine the cycle time for each assembly station. A form called Planning Sheet is used to collect measurements from a sample of ten observations.

Table 1. Process planning for cycle time data

Hoja de Planeación													
Proceso: Ensamble de carro				Encargados:				Fecha: 19/02/12					
Estación	Descripción del proceso	1	2	3	4	5	6	7	8	9	10	Tiempo promedio	Observaciones
1	Eje frontal	9.8	12.9	11.3	10.7	10.3	9.7	10.2	10.1	9.9	9.6	10.45	
2	Eje trasero	15.5	10.6	10.9	14.3	11.7	12.8	10.8	11.2	10.9	10.7	11.94	
3	Volante	42.2	34.4	39.7	35.6	40.1	38.9	41.7	40.3	36.8	35.1	38.48	Cuello botella
4	Parte trasera	26.7	27.2	23.6	24.5	26.8	25.6	27.4	22.7	23.9	24.2	25.26	Tiempo de ocio
5	Intalación de llantas	23.8	17.6	18.7	19.5	22.7	18.9	19.9	17.2	16.9	17.3	19.25	

Following is the Current Value Stream Map using the measurements above. A regular 480 min. shift is used to estimate the inventories in the process. Other metrics like up time and Change over are assumed by the team.

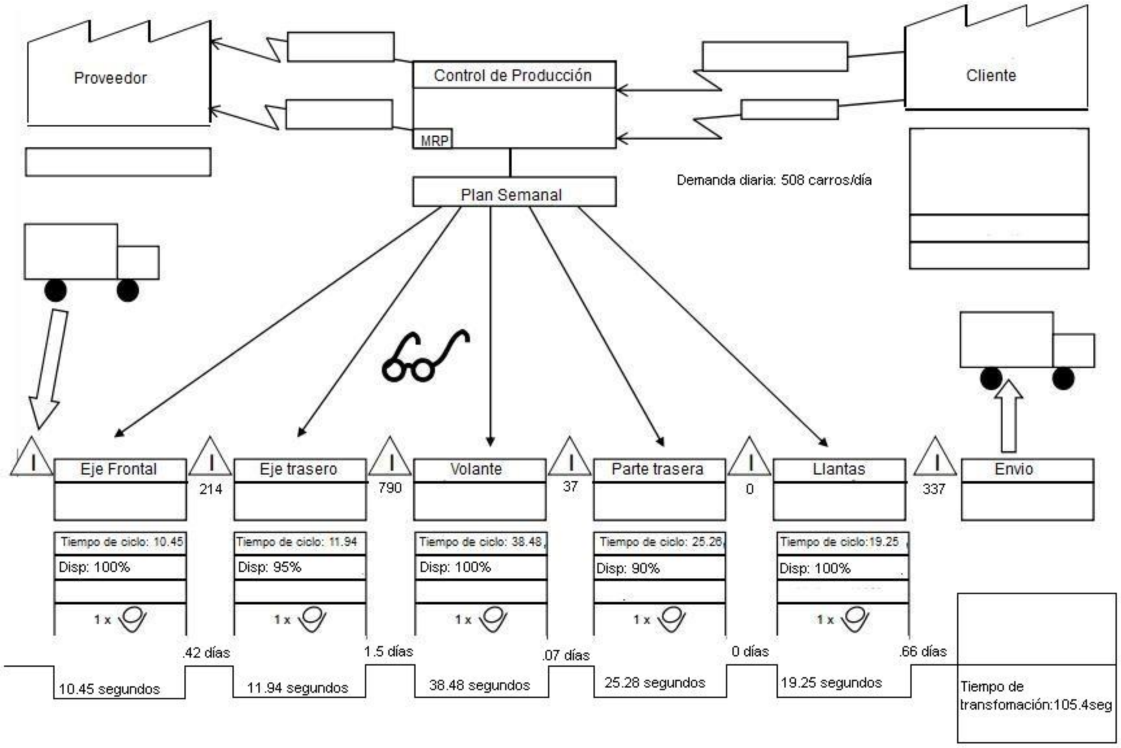


Figure 2. Example of Current Value Stream Map for the assemble process

To calculate the current line performance a specific demand has to be assumed. Students are freedom to establish the demand such that generates a takt time that will not be reached by all the assembly stations in the process.

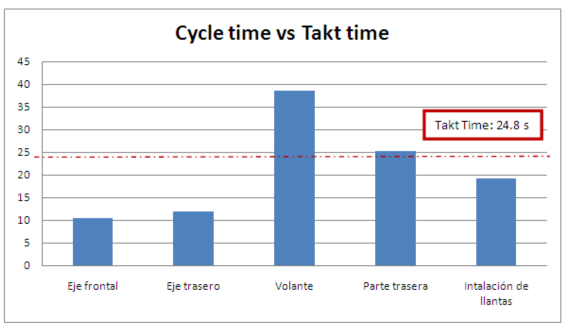


Figure 3. Current Cycle time vs Takt Time

Line current performance calculations are given as follows:

$$Man\ Target = \frac{105.39}{24.8} = 4.25 \approx 5\ operators$$

$$Line\ Balance\ Ratio = \frac{105.39}{(5 \times 38.48)} \times 100 = 54.77\%$$

$$Line\ Balance\ Efficiency = \frac{105.38}{(5 * 24.8)} * 100 = 84.98\%$$

Current State summary	
Operators	5
Takt	24.8 sec.
Total work	105.38 sec.
Balance Ratio	54.77%
Balance Efficiency	84.98%

Now, the assembly line has to be balance to fit the corresponding takt time. Those stations with cycle times are greater than the takt time, will transfer some activities to assembly stations with cycle time shorter than the takt time.

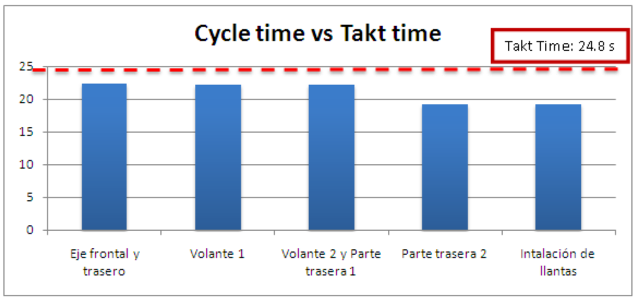


Figure 4. Current Cycle time vs Takt Time for balanced line

Assembly line balance performance calculation:

$$Line\ Balance\ Ratio = \frac{105.38}{(5 * 22.24)} * 100 = 94.76\%$$

$$Line\ Balance\ Efficiency = \frac{105.38}{(5 * 24.8)} * 100 = 84.98\%$$

Estaciones Balanceadas	
Operarios	5
Takt	24.8 sec.
Total work content	105.38 sec.
Balance Ratio	94.76%
Balance Efficiency	84.98%

Another assignment asked to students is to express the project in terms of the conventional A3 format.

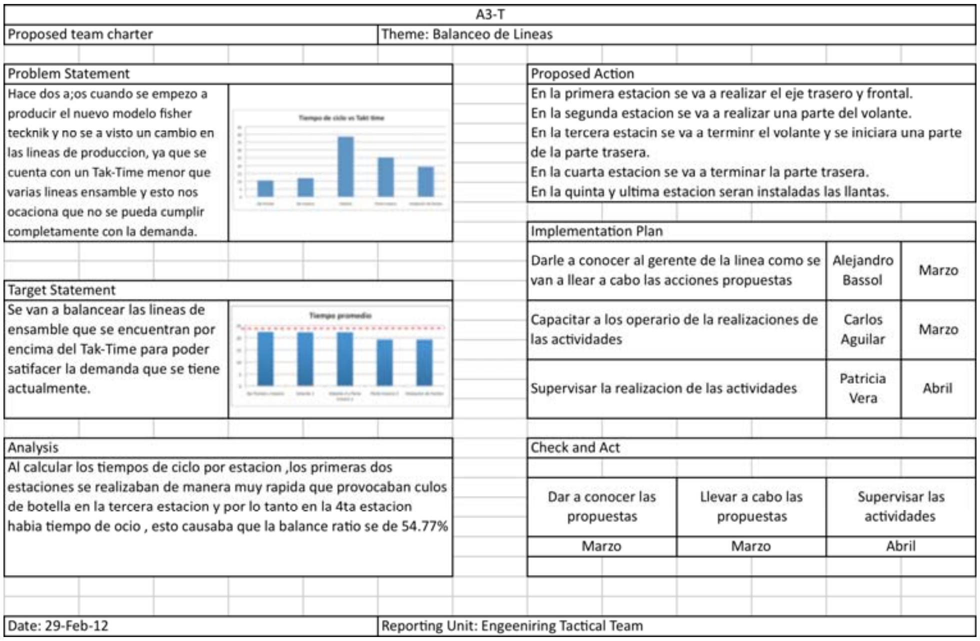


Figure 5. A3 format for project for balancing the assemble line

The future value stream map is drowning using alternative methods such as One peace flow, FIFO and kanbans and supermarkets.

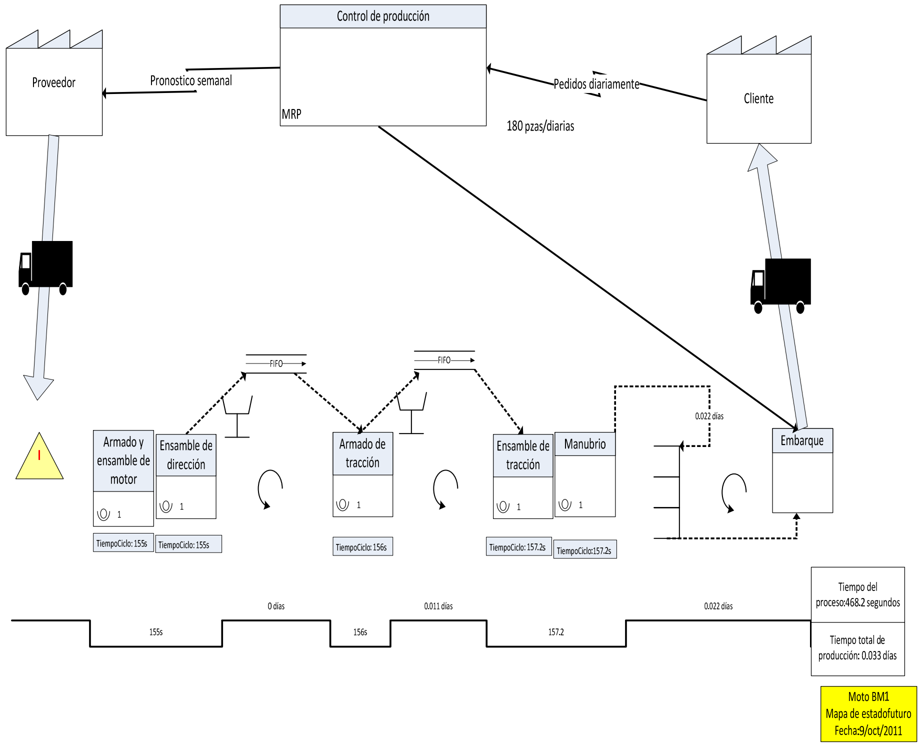


Figure 6. Example of Future Value Stream Map for the assemble process

4. RESEARCH FINDINGS AND DISCUSSION

All the six students teams achieved the expected goals according with the standards established in the corresponding rubric. At the end of the project students gave a presentation. This was to ensure the attainment of all the learning outcomes stated in the initial rubric. The average of the grade evaluation was outstanding obtaining an average of 92% of grading. The general mean of students satisfaction compared with tree previous cohorts, when this project approach was no used, was statistically significant at a 95% confidence, obtaining an increase of around nine percentage points. Students were somehow confused in the very beginning because of the lack of freedom for decision making in previous courses; but as soon as they start making their own decision from the initial step, when selecting the car model to assemble, they start becoming enthusiastic and responsible for their action. The time expended for developing the project outside class was approximately 18 hours each, making a total of 90 student-hours for the whole project including experimental work, analysis, and writing the final report. This time was large enough to complete the project. Several files containing technical information was available on the University Blackboard System for supporting the student understanding of technical aspects. While the project progress, regular sessions in classroom were dedicated to support students, the discussion mainly was for administrating the process rather than technical advice. Personal opinions from individual student as well as by all teams, revels a great satisfaction for this teaching-learning approach

5. CONCLUSIONS

A Project-based learning (PBL) was administered on some 30 students enrolled in the Lean Manufacturing course at the Engineering Department of the University of Monterey (México) in the Industrial Engineering academic curricula. The aims of this learning approach were to experiment evaluate the benefits of the method to increase the learning outcomes. Six groups of five students each were organized to develop the project in a two weeks span. During the project development a great engagement, enthusiastic, and motivation was evident in student's performance. All teams achieve the expected goals. The general satisfaction of students compared with previous cohorts was significant and revels a 9% of increase. Personal opinions from students also confirm a full successful learning approach.

REFERENCES

Morgan, Jeffrey, Creating Lean Corporations: Reengineering from the Bottom up to Eliminate Waste, Productivity Press, 2005.

Womack, James P., Jones, Daniel. Lean Thinking, Free Press, 2003.

Pascal, Dennis, Lean Production Simplified: A Plain-Lenguage Guide to the World´s Most Powerful Production System, Productivity Press, 2002.

Hobbs, Dennis P., Lean Manufacturing Implementation: A Complete Execution Manual for Any Size Manufacturer, APICS, 2004.

Bonwell, C. C., and J. A. Eison. 1991. "Active learning: Creating excitement in the classroom". ASHE-ERIC Higher Education Report No. 1. Washington, D.C.: The George Washington University.

Lundeberg, M. A., Kang, H., Wolter, B., del Mas, R., Armstrong, N., Borsari, B., . Herreid, C. F. (2011). "Context matters: increasing understanding with interactive clicker case studies. Educational". Technology Research and Development, 59, 645–671.

Jones, B. F., Rasmussen, C. M., & Moffitt, M. C. (1997). "Real-life problem solving: A collaborative approach to interdisciplinary learning". Washington, DC: American Psychological Association.

Thomas, J. W., Mergendoller, J. R., and Michaelson, A. (1999). "Project-based learning: A handbook for middle and high school teachers". Novato, CA: The Buck Institute for Education.

Moursund, D. (1999). "Project-based learning using information technology". Eugene, OR: International Society for Technology in Education.

Diehl, W., Grobe, T., Lopez, H., & Cabral, C. (1999). "Project-based learning: A strategy for teaching and learning". Boston, MA: Center for Youth Development and Education, Corporation for Business, Work, and Learning.

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. Clearing House, 83(2), 39-43.

Hunaiti, Z., Grimaldi, S., Goven, D., Mootanah, R., & Martin, L. (2010). “Principles of assessment for project and research based learning”. International Journal of Educational Management, 24(3), 189-203.

Felder, R., Woods, D., Stice, J., & Rugarcia, A. (2000). “The future of engineering education: II. Teaching methods that work. Chemical Engineering Education”, 34, 26–39.

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