Personal Learning Environments: Analysis of Learning Processes, Reflection, and Identity in an Academic Context

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Personal Learning Environments: Analysis of Learning Processes, Reflection, and Identity in an Academic Context

Abstract

The purpose of this paper was to examine and assess the current state of Personal Learning Environments (PLEs) of junior and senior engineering students at Universidad de las Américas Puebla (UDLAP). A survey (completely voluntary) was designed to elicit students’ PLEs. After pilot testing it with 42 students from a variety of engineering majors, the instrument was refined. The enhanced survey yielded 98 suitable responses (including in-depth interviews) from Food, Industrial, Chemical, Logistics, Civil, Mechanical, and Computer Systems engineering students. Furthermore, to strengthen understanding of their PLEs, mappings were conducted through infographics, in which selected students (n=28) represented and explained their own PLEs, describing relevant formal and informal learning activities that they usually perform by means of his/her PLE.

Results confirmed the influence of technological tools in learning experiences of engineering students and the cognitive skills they have developed during their formal education. Students emphasized that with the use of technology they acquired new skills to communicate and that they have more control over assignments. Through mapping of their PLEs, engineering students recognized their personal learning processes, as an exercise of metacognition. Triangulation of information (survey results, in-depth interviews, and mappings) allowed us to have a more comprehensive view of our engineering students’ PLEs. One particular feature frequently mentioned of PLEs is that students can configure and assemble them depending on their needs and with tools they are already using. Social networking enabled engineering students to build genuine learning communities. Studied PLEs helped engineering students to make visible for them how to take control of as well as manage their own learning. Analysis of PLEs revealed their potential to address the needs of engineering students for multi-sourced content and easily customizable learning environments.

Introduction

Universidad de las Américas Puebla (UDLAP) is a Mexican private institution of higher learning committed to first-class teaching, public service, research and learning in a wide range of academic disciplines including business administration, the physical and social sciences, engineering, humanities, and the arts. Since 1959, the Southern Association of Colleges and Schools Commission on Colleges (SACS-COC) has accredited UDLAP in the United States.

The introduction of Web 2.0 has revolutionized teaching models, methodologies, and tools. In parallel, there is an evolution of e-learning in which new technologies substituted “Virtual Learning Environments” based exclusively on CMS (Content Management System), LMS (Learning Management System), and LCMS (Learning Content Management System) platforms, with the more communicative and agile PLEs (Personal Learning Environments). The term Personal Learning Environment (PLE) describes the tools, communities, and services that constitute the individual educational platforms learners use to direct their own learning and pursue educational goals. A PLE is frequently contrasted with a learning management system in that an LMS tends to be course-centric, whereas a PLE is learner-centric.
A PLE refers not to a specific service or application but rather to an idea of how individuals approach the task of learning. A PLE is a system that helps learners take control of and manage their own learning. This includes providing support for learners to set their own learning goals, manage their own learning in terms of both content and process, as well as communicate with others in the process of learning and thereby achieve their learning goals. Therefore, our PLE is composed of the different tools we use in our daily life to learn, including formal and informal learning environments from our individual experiences. Through the PLEs we can recognize the processes of learning, reflection, and identity that individuals develop in a context, mediated or not by technology. However, nowadays technology is a necessary tool widely used by individuals who are part of a formal learning community. Thus, a PLE usually involves using a combination of electronic devices, applications, and services.

In his/her PLE, the individual uses skills that he/she has developed as a learner. In an educational context learners apply these skills, that have been acquired or not in it, and yet are necessary to achieve objectives established for that context. In recent years, the skills that learners have developed to establish their PLEs have been directed toward the use of digital technologies, software, and social networks, because it is increasingly common in educational contexts their use as instruments for learning. Casquero et al. mention that a PLE depends on the preferences and needs of the user and regardless of the elements it contains, what really matters is that both, teachers and students, understand the functionality of the tools they use in their PLEs and learn to make efficient use of them to carry out their teaching and learning activities.

Although PLEs are built for personal use, they involve communication and increasingly social tools, promoting networked learning scenarios. Knowledge management, syndicating resources, trustworthiness and assessment on the assemblage of resources are actual research issues related to the improvement of PLEs. Without a pedagogical value, PLEs cannot be viewed as educational tools, but perhaps advanced, user-friendly file management tools. Hence, Türker and Zingel proposed that such a user-centric tool when adequately utilized, influences the formal learning process so much that meaningful and constructive activities are committed more often than in rudimentary informal learning; furthermore, that self-regulation can be scaffold by a PLE, activating higher order learning competencies even in very young users.

Therefore, the purpose of this paper was to examine and assess the current state of PLEs of senior engineering students at UDLAP.

**Methodology**

A survey (completely voluntary) was designed to elicit students’ PLEs. After pilot testing it with 42 students from a variety of engineering majors, the instrument was refined. The enhanced survey yielded 98 suitable responses (including in-depth interviews) from Food, Industrial, Chemical, Civil, Mechanical, Logistics, and Computer Systems engineering students.

One of the purposes of the survey was to identify the current status of our students regarding the use of technological tools that are part of their PLEs, as well as their information sources, and networks based on Posada's proposal who argues that the six basic tasks that are performed in a PLE are:
1. Search and filter information of interest
2. Organize content
3. Communicate with others
4. Create new content
5. Post to share with the community
6. Collaborate with others in collective production tasks

These activities are familiar in formal education environments that involve the implementation of basic skills, especially several regarding digital competencies. Consequently to perform these tasks the fundamental elements of a PLE are:

- **Tools or applications.** Denotes the programs installed on your digital device as well as online services. These applications can be classified according to the task for which they are utilized: search, organize, communicate, create, publish, or collaborate.
- **Information sources.** It refers to sites that are consulted. The repertoire will vary depending on the subject or field of knowledge.
- **Personal Learning Network (PLN).** It is the group of people with whom we have contact and with whom we share the content created.

It is important to note that a PLE is constantly evolving. Not only in the selection of its objectives, content, and tasks; but also incorporating and discarding information sources, tools, networks, etc.

Tasks performed by students in their PLEs were classified by means of the Bloom's Digital Taxonomy proposed by Churches. This proposal is an enhancement to Bloom's Revised Taxonomy that attempts to account for the new behaviors and actions emerging as technology advances and becomes more ubiquitous. Bloom's Revised Taxonomy describes many traditional classroom practices, behaviors and actions, but does not account for the new processes and actions associated with Web 2.0 technologies, the exponential growth in information, increasing ubiquitous personal technologies, or cloud computing. Bloom's Digital Taxonomy isn't about the tools or technologies rather it is about using these to facilitate learning. Outcomes were measured by competence of use and most importantly the quality of the process or product by means of associated rubrics developed by Churches. For example, *bookmarked a resource* was categorized of no value if the resource was inappropriate, invalid, out of date, or inaccurate.

Anderson and Krathwohl in the Bloom's Revised Taxonomy identified nineteen specific cognitive processes to further clarify the bounds of the six categories of the cognitive process dimension, which represents a continuum of increasing cognitive complexity, from remember to create. These were utilized to categorize students’ responses as well as the processes developed in the Bloom's Digital Taxonomy by Churches; an example of this is the following for the cognitive process entitled *remember*:

**Possible Activities Related to the Cognitive Process Remember**

- **Recitation** (Word Processing, Mind map, flashcards, presentation tools)
- **Quiz/Test** (Online tools, Word Processing (local – Word, pages, Open Office or online – Google Documents, Zoho Documents, Thinkfree etc.), Cue sheets)
- **Flashcards** (Moodle, Hot potatoes, scorm objects)
- **Definition** (Word Processing – bullets and lists, (local – Word, Pages Open Office or online – Google Documents, Zoho Documents, Thinkfree) simple Mind maps, wiki, Moodle Glossary, Online services like Ask.com, Cloze exercises, etc.)

• **Lists** (Word Processing – bullets and lists, Mind map, Web publishing – personal web page, blog journal, wall wisher, post it notes) Bookmarking internet browsers using favorites and bookmarks, web 2.0 tools del.icio.us & diigo

• **Basic Searches** - search engines, (Google, excite, ask, yahoo, metacrawler etc.) library catalogue, Clearinghouses

Keywords: Recognizing, Listing, Describing, Identifying, Retrieving, Naming, Locating, Finding, Bullet pointing, Highlighting, Bookmarking, Social networking, Social bookmarking, Favorite/local bookmarking, Searching, Googling

Further details for the cognitive processes entitled *Understand, Apply, Analyze, Evaluate, and Create* can be found in Curches⁹. Activities performed by students in their PLEs could be further classified by means of Bloom's Revised Taxonomy¹⁰ knowledge dimension that represents a range from concrete (factual) to abstract (metacognitive); however this was not part of this study.

The first part of the survey¹¹ was divided into 3 sections in which students were asked to evaluate in a five-point scale if they: 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, or 5=strongly agree. The second part of the survey contained open questions so that students have a space to write about their PLEs as well as his/her learning through technological tools, several information sources, and their PLNs.

The information obtained was classified into quantitative and qualitative data. To do this, we created a worksheet in Excel™ for quantitative analysis of data. On the other hand, qualitative information was analyzed by means of the Atlas.ti™ software, which was utilized to sort and categorize the information obtained. The software allowed to organize student responses and facilitated the selection of units of meaning and order into categories; its Hermeneutics Unit was utilized to encode primary documents created by selecting fragments of responses and assigning a code to then form families that permitted the analysis¹¹.

Furthermore, to strengthen understanding of their PLEs, mappings were conducted through infographics, in which selected students represented and explained their own PLEs, describing relevant formal and informal learning activities that they usually perform by means of his/her PLE. Infographics were selected in order for them to make a visual representation that describes graphically the elements that are part of their PLEs. For the design of the infographics an online tool called Easel.ly was utilized. This tool allowed students to realize infographics from templates that they designed and integrate the elements they considered as important to illustrate their PLEs. To make infographics, an instruction was given to students to identify the three fundamental elements of a PLE: tools, resources, and networks⁸ so they could determine which ones were used in their learning processes. Twenty-eight metacognitive maps were obtained from Industrial, Chemical, and Logistics Engineering students, which were examined with Atlas.ti software, since it allows analyzing images. With this software the categories of analysis from the images that students displayed in their infographics, were identified. The primary documents that were part of Atlas.ti Hermeneutics Unit were divided by engineering major, which facilitated the analysis of the results.
The first analysis corresponded to the fundamental elements of a PLE: tools or applications, sources of information, and PLNs. The second analysis of metacognitive maps corresponded to models of PLEs. For this, the classification proposed by Calvo that illustrates through schemes, the possibilities offered by the different types of environments was considered. The four types of models proposed by Calvo are:

1. **PLE by goals and tasks.** This environment is based on the use of platforms and virtual spaces. The center around the environment is the person, the individual. It moves towards the goals by arrows of no return, or what is the same, following a one-way communication model. It represents PLE use but not an impact of that use on the user. It is related with operating behavior and no significant learning. Elements are unrelated; each has its role within the PLE but does not interact with the rest of it. It is worth noting that the environment is not encompassed as a whole, it not forms a unit because each task is individual (and reaffirms its individuality).

2. **PLE by tools or products.** It is characterized by a codification of the elements based on their technical potential. The user has a scheme more or less categorizable of possibilities to which can go directly or indirectly linked to the product that can get of them. They are not related with tasks themselves, because the relationship between the user and the tool is not set in terms of the activity but based on the offered results. The PLE center is the individual who interacts with the elements that make him/her adopting two roles: receiver and transmitter. It is important to distinguish that among the elements of the environment there are more people, a social context that participates in the process, able to generate opinions and actively working together.

3. **Connectivist PLE.** This model reflects some of the basic principles of connectivism, such as “learning is a process of connecting specialized nodes or sources of information” or “learning may reside in non-human devices”. Their application must meet other principles that give meaning to connectivism and that are point to the role of the individual as an agent of decision, critical, and flexible. At first glance we don’t find an organization neither for assignment or goal, even for the space occupied on the graphic. Items are organized by color, but each type is interspersed with other, drawing a mixed puzzle whose performance is linked to the subject (and its symbolism). The center of the process is not the individual but the way the elements of the PLE are related to each other.

4. **Lifelong learning PLE.** This model responds rather to a distribution of any of the models shown above but along the professional life of a person, in his/her process of continuous training. The model focuses a limited number of elements (in this case all are virtual platforms) that give different responses and products. These elements overlap in time, are constantly present, and are chosen and discarded as needed.

**Results and discussion**

**Survey results**

**Devices and their uses**
Currently there are a large number of technological devices on the market for various uses in connection with learning. Our results (Figure 1) show that students most frequently utilized mobile phones (mainly smartphones). The laptop is another device commonly used by engineering students. Desktop computers are still used by students, but they did not mention whether they utilized them in the university or at home. Moreover, several students also use iPads and tablets to learn.
Engineering students utilize various technological devices and have ubiquitous access to the wireless network throughout the campus, which allows them to use them inside and outside the classroom. The most common uses of the devices mentioned by them are performing classroom-related queries and searching for information online, plus they were considered a great support for carrying out homework and assignments, as well as for reading documents, and communicating with other students (Figure 2).

Given the context, the use of technological devices in the classroom can be a great help for both students and teachers; thus the responsibility for both is to properly utilize them during their learning processes. Results confirmed the influence of technological tools in learning experiences of our senior engineering students and the cognitive skills they have developed during their formal education. Students emphasized that with the use of technology they acquired new skills to communicate and that they have more control over assignments.

**Cognitive processes**

As mentioned, the Digital Taxonomy by Churches\(^9\) was used to identify the cognitive processes that our senior engineering students have developed during their undergraduate learning.
processes using technology. Results indicate that according to this taxonomy, students identified several cognitive processes related to the six categories of the cognitive process dimension proposed by Anderson and Krathwohl in the Bloom's Revised Taxonomy, representing a continuum of increasing complexity, from remember to create (Figures 3 and 4).

![Figure 3. Processes related to the Bloom's Revised Taxonomy Cognitive Domain that studied engineering students (n=98) performed by means of technological devices](image1)

![Figure 4. Processes related to the Bloom's Revised Taxonomy Cognitive Domain that studied engineering students (n=98, classified by major) performed by means of technological devices](image2)

Specific skills (classified by means of the Digital Taxonomy) that students believe they have developed include the following:

1. **Remember** (retrieving, recalling or recognizing knowledge from memory. Remembering is when memory is used to produce definitions, facts or lists, or recite or retrieve material):
   a. Recitation (Word Processing, Mind map, presentation tools)
   b. Quiz/Test - Online tools (Blackboard), Word Processing (Word, Pages, Office 365, Google Documents, etc.).
   c. Definition - Word Processing (local or online – Word, Pages, Office 365, Google Documents, etc.), simple Mind maps, wikis, Moodle Glossary, etc.
d. Facts (Word Processing, Mind map, Internet, discussion boards, email, etc.).
e. Lists (Word Processing, Mind map, Web publishing, post it notes, etc.).
f. Bookmarking Internet browsers using favorites and bookmarks.
g. Basic Searches - search engines (Google, yahoo, YouTube, etc.), university library catalogue, etc.

2. Understand (constructing meaning from different types of function be they written or graphic):
   a. Summary (Word Processing, Mind map, web publishing, Simple DTP products – blog journals & simple webpage construction, collaborative documents - Google documents, wikis, etc.).
   b. Explanation (Word Processing, Mind map, web publishing, simple DTP Products – blog journals & simple page construction, collaborative documents - Google documents, YouTube, wikis, etc.).
   c. Show and tell (Word Processing, presentation – online & desktop based, graphics, audio tools - sound recorders & podcasting tools, video tools, Mind maps, etc.).
   d. Advanced and Boolean searches - advanced search features.
   e. Blog journaling - bloglines, blogger, etc.
   f. Diary/Journal (blogging, Ning, Facebook, Moodle, etc.).
   g. Categorizing, Tagging, Comments & Annotating - social bookmarking, discussion boards, threaded discussions, adobe acrobat, blog readers, Firefox, etc.
   h. Subscribing – RSS aggregators.

3. Apply (carrying out or using a procedure through executing or implementing. Applying relates and refers to situations where learned material is used through products like models, presentation, interviews and simulations):
   a. Illustration (Corel, CAD/CAM, Paint, online tools, Comic creation tools) Simulation (graphic tools, Google sketchup, Aspen, LabView, etc.)
   b. Sculpture or Demonstration (CAD/CAM, graphics, screen capture, 3D images, Blender, etc.) audio and video conferencing - Skype.
   c. Animation & screen capture (Camtasia, Camstudio, iMovie, Movie maker, Grab, Snagit, Office Mix, etc.).
   d. Presentation - Impress, PowerPoint, Google presentation, Skype, interactive whiteboard collaboration using e-tools, audio and video conferencing, etc.
   e. Interview (Word Processing, Mind map, podcast, vodcast, audacity, sound recorder, Skype, etc.).
   f. Performance (Podcast, vodcast, film, audio and video conferencing, VoIP, audio recording, speech, PowerPoint Show, Office Mix, etc.).
   g. Editing - video and sound tools, Wiki editing, Simple DTP product. Developing a shared document, Playing – online games, simulations like Aspen, Polymath, and LabView, etc.

4. Analyze (breaking material or concepts into parts, determining how the parts relate or interrelate to one another or to an overall structure or purpose. Mental actions include differentiating, organizing and attributing, as well as being able to distinguish between components):
   a. Survey & process (Web based tools – Survey monkey, Google forms, embedded polls and votes, social networking tools, Word Processing, Spreadsheets, email, discussion boards, cell phones and texting, etc.).
   b. Database (relational; databases using MySQL and Access, Flat file database using Spreadsheet, wikis, Geographical information systems or GIS - Google earth, Google Maps, Maps Flickr, etc.).
   c. Abstract (Word Processing, web publishing, etc.).
   d. Relationship maps - Herring or fish bone mind maps, SWOT Analysis, Venn, Cmap, Mind mapper, freemind online tools, etc.
   e. Report (Word Processing, spreadsheets, presentation, web publishing – web page or blog entry, etc.).
   f. Graph (Spreadsheets, digitizer, online graphing tools).
   g. Spreadsheet & Data Processing (Calc, Excel, Numbers, online spreadsheet tools, etc.).
   h. Checklist (Word processing, survey tools, online polls, Spreadsheets, etc.).
   i. Chart (Spreadsheets, digitizer, mind mapping tools, online tools, etc.).

5. Evaluate (making judgments based on criteria and standards through checking and critiquing):
   a. Debate or panel discussion (Word Processing, podcasting or vodcasting, Mind mapping, Chatrooms, IM, email, Discussion boards, video and Phone conferencing, Collaboration tools – webinar tools - elluminate, etc.).
   b. Report or Evaluation (Word Processing or web published – Blackboard, Report, blog entry, wiki entry, web page, DTP, Presentation, Camera, etc.).
c. Investigation (Internet, Online tools, camera, Word Processing, GIS [Google earth, Google Maps, Flickr]), Verdict, Judgment or Conclusion (Word Processing, DTP, Presentation, video, audio, conference, etc.).
d. Persuasive speech (Word Processing, Sound recorder, Office Mix, Mind map, Cmap, etc.).
e. Critical commenting, moderating, reviewing, and/or posting - discussion boards, forums, blog, wikis, Twitter, threaded discussions, bulletin boards, chatrooms, etc.
f. Collaborating - discussion boards, forums, blog, wikis, Twitter, threaded discussions, bulletin boards, chatrooms, video conferencing, chat-rooms, instant messaging, video messaging, audio conferencing, etc.
g. Networking - social networking tools, A/V conferencing, email threads, telecommunications, instant messaging, live classrooms - ellluminate, etc.
6. Create (putting the elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure through generating, planning or producing16):
a. Media production - (Movie maker, iMovie, Adobe premier elements, online tools, etc.).
b. Presentation (presentation tools - PowerPoint, Keynote, Impress, Zoho presentation tool, Photostory, Google present. Comic creation tools, Prezi, voicethread, Office Mix, etc.).
c. Story (Word Processing or web publishing, DTP, Presentation, podcasting, photostory, voicethread, Comic creation tools, etc.).
d. Programming - Visual Studio, Marvin, Lego Mindstorms, Scratch, Alice, Aspen, LabView, etc.
e. Planning - Project Management (Office Project, Word Processing, Gannttproject, Openproj, etc.) calendars, flow charts, mind maps, etc.).
f. Blogging/vlogging - Blogging tool, blogger, wordpress, edublogs, classroom blogmiester, bloglines voicethread, Skype, etc.
g. Modeling (Sketchup, Blender, Maya3d PLE, Autocad, tinkercad, thingiverse, Cubify, Mathematica, SystemModeler, Aspen, Minitab, SPSS, several statistical software, Mathcad, etc.).
h. Song (finale notepad, garageband, Audacity, podcasting, recording narration, Office Mix, etc.).

As can be seen in Figures 3 and 4, cognitive processes related to the cognitive process entitled create should be further promoted in every studied engineering major in order to enhance senior students’ achievement of program outcomes related to this process, which have been emphasized by many national and international organizations such as AI14 and ABET15, respectively.

Learning tools
These are understood as those that are designed to facilitate the learning process. In this sense, students use tools for learning activities in order to achieve course learning and program outcomes. On the one hand there are technological, and on the other “traditional” (without the use of technology) tools. Our results give an indication that traditional tools are still widely used and preferred by many students when learning (blue bars in Figure 5). However, many technological learning tools are being considered by senior engineering students as useful tools in their learning processes (orange bars in Figure 5). It is important to enhance learning the use of both, “traditional” and technological tools with which students can learn more and better. Incorporation of information and communications technologies in schools have transformed teaching and learning; however, are the contexts of the use of these technologies which will determine their impact on educational practices and its ability to transform teaching and improve learning16.

Students’ open responses with regards to the influence of technological tools in their learning experiences established (described in detail elsewhere11) that by using technological tools:

- They had immediately accessible information
- Downloaded books, videos, articles, etc., without having to go to the library
- Specialized software was readily available for different engineering areas
• Classes became much more interactive
• They became autonomous learners
• They better managed their time
• Received real-time feedback
• The information available for them was through videos and not only documents
• Available applications allowed them to perform activities/exercises to complement classroom activities
• Had better control of their homework and assignments
• Communication was more effective
• They immediately shared information with others
• They were able to store information in a practical way

Communication and collaboration skills
Collaboration and communication are 21st Century skills of increasing importance and ones that are used throughout the learning process\(^9\). In some taxonomic levels the communication and collaboration verbs are included as elements of the Digital Taxonomy and in others they are just mechanisms which can be used to facilitate higher order thinking and learning. Therefore, collaboration and communication are 21st Century essential skills; furthermore they are key elements of each of the UNESCO’s four pillars that are fundamental principles for reshaping education: learning to know, learning to do, learning to live together, and learning to be\(^17\). So to prepare our students, our teaching should also model collaboration and communication\(^9\). A vast array of collaborative-communicative tools is available; wikis, classroom blogs, collaborative document tools, social networks, social bookmarking and learning management systems. Many are available at no cost. These tools are enablers of collaboration and communication; thus, potentially enablers of 21st century teaching and learning.

From the survey and corresponding interviews it was evident that our students through the use of various technological devices developed such collaboration and communication skills, either synchronously or asynchronously. Our senior engineering students believe that collaboration and communication skills they have developed are mainly through the use of email, instant messaging, and chats, by their participation in social networks where they communicate with their peers; also by virtual collaborating, video conferencing, as well as the possibility of questioning electronic publications or even contribute to them (Figure 6). Studied engineering
students mentioned that they primarily use email to communicate with teachers, while they predominantly chat, social network, and instant message to communicate with their classmates. Moreover, they also mentioned had the opportunity to communicate remotely with some professors from other universities, but rarely have been synchronously. Their virtual participation in publications is primarily within the university community and in social networks. Collaboration and communication skills developed through the use of technology may be oral and/or written depending on the medium or tool. Our results show that senior engineering students have developed more written communication skills and manifest mastery of skills to discuss in forums, moderate discussions, or make negotiations through electronic networks.

It was clear from the survey and corresponding interviews that our senior engineering students performed in their PLEs the six basic tasks that are part of Posada's proposal: search and filter information of interest, organize content, communicate with others, create new content, post to share with the community, and collaborate with others in collective production tasks.

**Metacognitive maps**

Adell and Castañeda established that a PLE includes what an individual consults to inform him/herself, the relations that he/she establishes with such information and between that information and other consults. At the same time, a PLE includes those people that serve as reference for him/her, the connections among these people and him/herself, and the relationships among these people and others that eventually may be of interest for him/her that serve to rebuild relevant information and knowledge, both in the phase of reflection and individual recreation, as in the phase in which it helps to reflect on others for such reconstruction.

**Tools or applications (Tools)**

Engineering students use selected software specialized for their majors (Table 1), which determine the function of several of the tasks they perform. Chemical Engineering students make more use of specialized software than students from Industrial and Logistics Engineering majors.
online, being the most mentioned Office; however, it is not clear the type of work or tasks that students perform using such software suite. Considering that a “PLE serves to keep abreast of innovations in our respective professional and academic fields”, the use of tools may vary, depending on the needs and interests of the user in each context and circumstance; therefore, presupposes a critical look at the tools used to perform a task to learn\textsuperscript{19}.

| Tools or applications displayed in the metacognitive maps from Industrial, Chemical, and Logistics Engineering students (n=28) |
|---|---|---|---|---|
| | Industrial | Logistics | Chemical | TOTAL |
| AspenTech | 0 | 0 | 4 | 4 |
| Autocad | 1 | 0 | 1 | 2 |
| Chegg | 1 | 0 | 0 | 1 |
| Dyknow | 0 | 0 | 2 | 2 |
| Lingo | 1 | 0 | 0 | 1 |
| MicroStation | 0 | 0 | 1 | 1 |
| Minitab | 2 | 0 | 0 | 2 |
| Office | 3 | 2 | 4 | 9 |
| TOTAL | 8 | 2 | 12 | 22 |

**Information sources (Resources)**

Websites that studied engineering students consulted vary in their repertoire. Most frequently they visited sites like YouTube to watch videos as well as online academic journals but it depended on the function of the topic to investigate. Those who visited more websites were Industrial Engineering students (Table 2).

| Digital information sources displayed in the metacognitive maps from Industrial, Chemical, and Logistics Engineering students (n=28) |
|---|---|---|---|---|
| | Industrial | Logistics | Chemical | TOTAL |
| Blogs | 0 | 1 | 1 | 2 |
| TV Channels | 5 | 1 | 3 | 9 |
| Newspaper | 1 | 1 | 1 | 3 |
| Digital Books/Journals | 1 | 4 | 5 | 10 |
| Wikipedia | 5 | 2 | 1 | 8 |
| Videos (YouTube) | 6 | 4 | 2 | 12 |
| TOTAL | 20 | 18 | 17 | 44 |

Metacognitive maps displayed not only the sources of information that students visit on the web, but also those sources that were considered above as “traditional”. Physical books are more
utilized than many other sources of information (Tables 2 and 3). Despite the easy access to information online, students continue to use physical books (Table 3).

Table 3. “Traditional” information sources displayed in the metacognitive maps from Industrial, Chemical, and Logistics Engineering students (n=28)

<table>
<thead>
<tr>
<th>Source</th>
<th>Industrial</th>
<th>Logistics</th>
<th>Chemical</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labs</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Physical Books</td>
<td>4</td>
<td>6</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>Physical Journals</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>TOTAL</td>
<td>8</td>
<td>9</td>
<td>12</td>
<td>29</td>
</tr>
</tbody>
</table>

A PLE includes the use of different tools, information sources, and activities that correlate with the knowledge acquired throughout a person’s life, and are determined by how he/she learns. Therefore, sources of information and tools that are considered by users as valid and reliable to allow them learning experiences in one or more contexts were clearly displayed in their PLEs.

Personal Learning Network (Networks)

PLNs are formed with those who are close to the user or have contact with him/her to share information or experiences that help him/her to learn. A PLE not only conforms an environment mediated by technology, but also an environment of direct relationships with others that enables learning. Engineering students displayed in their metacognitive maps that their teachers, friends, and family are important elements of their learning environment, and they are those who appear in their PLNs (Table 4).

Table 4. Personal Learning Network members displayed in the metacognitive maps from Industrial, Chemical, and Logistics Engineering students (n=28)

<table>
<thead>
<tr>
<th>Member</th>
<th>Industrial</th>
<th>Logistics</th>
<th>Chemical</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friends</td>
<td>2</td>
<td>2</td>
<td>9</td>
<td>13</td>
</tr>
<tr>
<td>Family</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>Teachers</td>
<td>2</td>
<td>3</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>TOTAL</td>
<td>5</td>
<td>9</td>
<td>24</td>
<td>38</td>
</tr>
</tbody>
</table>

A PLE has an eminently social part and a personal (individual) part. On the social side there are at least two forms of relationship that are clearly different; in one form, he/she learns from what others do, but without interacting with them, and in the other form, he/she learns by interacting with others sharing among them information and learning from each other\(^\text{18}\). As stated by Díaz-Barriga and Vázquez\(^\text{19}\) building a PLE involves a continuous cycle of (re)construction of knowledge, as well as personal and collective development, creating information and communication networks among authors and users.
Types of Personal Learning Environments

Metacognitive maps displaying PLEs from Industrial, Chemical, and Logistics Engineering students (Figure 7) demonstrated that the PLE by goals and tasks model is the most common among them. In this type of PLE model (Figure 8) the use of platforms and virtual learning spaces are clearly identified. The center of this type of PLE is the student; unidirectional elements are related to networking and/or various tools for learning.

![Figure 7. Types of Personal Learning Environments displayed in the metacognitive maps from Industrial, Chemical, and Logistics Engineering students (n=28)](image)

Figure 8. An example (in Spanish) of a Personal Learning Environment by goals and tasks

Figure 9 shows a PLE by tools or products, the center is the individual who interacts bi-directionally with the elements of the PLE, taking both receiver and transmitter roles. In this type of PLE it is very important the existence of a social network, because there is interaction with others to generate opinions and actively work in a group to learn, but the center is still the author of the PLE.
Figure 9. An example (in Spanish) of a Personal Learning Environment by tools or products

Figure 10. An example (in Spanish) of a connectivist Personal Learning Environment
Figure 10 shows a Connectivist PLE, in this type (model) of PLE, the center is not the individual but the way the elements of the PLE are related to each other\textsuperscript{13}; the connections that allow he/she to learn have more importance than his/her current state of knowledge. The successful application of this model of PLE does not depend on formal or non-formal contexts, but on the user’s ability to see connections between fields, ideas, and concepts; to decode and interpret these nexus. This is due to the idea that information is a node and knowledge is a connection\textsuperscript{19}.

In a further analysis performed to metacognitive maps, it was found that there are differences among studied majors in the types of PLEs produced by students. Numbers of representations of PLEs are as follows: PLE by goals and tasks (6, 2, and 4), PLE by tools or products (2, 3, and 6), or connectivist PLE (1, 3, and 1) for Industrial, Logistics, and Chemical Engineering students, respectively. These results once again show the influence of context on learning. In every one of the types of PLE types (models) an approach to learning could be clearly identified, which can be formal or informal; that is, that in studied metacognitive maps, learning goes beyond the classroom and the teacher-centered classroom model.

Final remarks

Triangulation of information (survey results, in-depth interviews, and mappings) allowed us to have a more comprehensive view of our engineering students’ PLEs. One particular feature frequently mentioned was that students can configure and assemble PLEs depending on their needs and with tools they are already using. According to the data, our senior engineering students are using many of the available tools while the vast majority accesses the Internet with their smartphone.

Overall, students felt their PLEs empower them to make their learning more personal, connected, social, networked, and open. PLEs enabled students to connect and share information more socially, effectively, and efficiently by linking multiple tools. Social networking enabled our engineering students to build authentic learning communities through context-rich social interaction rather than content focus only\textsuperscript{20}. They are participating in communities of practice where they contribute content, engage in conversations, and make connections. Students were able to project positive social digital identities that can assist them to become network community learners. Students who usually utilize smartphones realized that they were actively engaged in learning whenever and wherever they prefer. Additionally, they appreciated the ability to access course materials after finishing their courses, since they can continue learning from the courses’ resources.

Studied PLEs helped studied engineering students to make visible for them how to take control of and manage their own learning. By uploading courses’ projects, cases, homework, and so on into their PLEs they were able to store their experience, reflection, knowledge, skills, and wisdom as well as create their own knowledge management and e-memory system\textsuperscript{2}. Engineering instructors should promote the construction of students’ PLEs as a metacognitive exercise to recover the individuality of the learner while making it visible for him/herself as well as for instructor and peers his/her learning processes.

Analysis of our senior engineering students’ PLEs revealed their potential to address the needs of formal and informal engineering learners for multi-sourced content and easily customizable
learning environments. In a Personal Learning Environment, the learner would utilize a set of tools, customized to his/her needs and preferences inside a single learning environment. These tools would allow the learner to: learn with other people, control his/her learning resources, manage the activities they participate in, and integrate his/her learning.21

Nowadays we are obtaining metacognitive maps from selected engineering students (already included in the survey and interviews) from majors that were not possible to obtain previously (Food, Civil, Mechanical, and Computer Systems that are not included in this report) in order to strengthen understanding of our senior engineering students’ PLEs.

Future empirical research should explore whether the results concerning Personal Learning Environments found in this study generalize to other kinds of engineering domains as well as different populations. Given the exploratory nature of this study, we recognize its limitations of generalizability. However, our findings are valuable in showing us meaningful directions for future research in the field both technically and pedagogically. We are planning to conduct studies regarding needs assessment, usability tests, and learning outcomes assessment in PLEs. In addition, future research should also be carried out especially on the detailed description and validation of the studied models and taxonomies. Nevertheless, to the degree that engineering education embraces the use of PLEs to better prepare students for functioning in everyday and professional contexts, a better understanding of studied processes is required. Much more engineering education research on PLEs is needed.

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