Design of Flexible and Open Learning Management Systems using IMS Specifications. The Game·Tel Experience

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The IMS consortium is one of the most active stakeholders in the Learning Technology standardization field. Among its latest outcomes, the proposals to communicate heterogeneous systems and integrate external tools into existing LMSs stand out. This paper describes the adoption of these recent IMS specifications to integrate external tools and applications into the Game·Tel learning platform. Although Game·Tel was originally designed to support game-based learning in a multi-device environment, this paper will demonstrate how the IMS specifications have allowed us to easily integrate a wide range of existing applications with a clear potential for education and training.

Keywords: External Tool, Tool Provider, Tool Consumer, IMS Learning Tools Interoperability, IMS Learning Information Services.

ACM Classification: H.3.4 Systems and Software, K.3.1 Computer Uses in Education

1. Introduction

Educational games provide important advantages for learning (Squire, 2003; Garris, Ahlers and Driskell, 2002): increase the motivation of the learner, personalisation, rich media experiences, etc. Taking into account these principles, game-based learning has been envisaged as a promising way to face technology-based learning demands. The Game·Tel project (Game·Tel Consortium, 2012) was originally proposed to develop an e-learning environment facilitating the use of games in a virtual environment.

The project involved partners from different universities, private companies and research institutes with a solid background in a range of fields from game-based education (Torrente et al, 2010) to IPTV (Goyanes et al, 2008). As the main background, the project was built over the <e-Adventure> platform (Torrente et al, 2010), a framework providing an authoring tool and player for game-based educational environments.

Using <e-Adventure> as an initial starting point, Game·Tel aimed at extending it by adding multi-device support, with a special focus on TV environments using the IPTV technology. The project also had as a goal to support full accessibility, in order to make sure that people with disabilities could use the system. Another goal was to provide support for social networking.
Finally, it was required to create a framework to easily integrate all the developed systems among them and with third-party contents or applications that could be useful for educational purposes. In this paper we focus on the latter objective of the Game·Tel project: to easily integrate external, potentially developed by different vendors, tools and applications. Our hypothesis was that, if we were able to develop an open and flexible integration framework, then the set of games available through the original <e-Adventure> platform could be also easily integrated following the same approach. Therefore, further maintenance and extensions in the project would be easier and the user would perceive the system as a single tool rather than a set of different separated pieces of applications. The integration of new software modules would allow the system to grow providing new functionalities to the end-user without increasing the complexity of the underlying platform.

As integration and communication among distributed software platforms involves the agreement on common APIs and interfaces, we researched existing alternatives in the learning technologies area. After this research, the IMS specifications, namely IMS Basic Learning Tool Interoperability and IMS Learning Information Services (see next section), showed as the more mature and accepted alternatives. This ensures that a wide range of tools and applications compliant with these specifications could be easily integrated. The developed system was tested in practice through a set of pilots aimed at validating different aspects of Game·Tel. Given the original objectives of the project as a whole, we included two groups of end users in these pilots, one with and one without disabilities. Therefore, the accessibility of the system was also tested.

Section 3 in this paper describes the main software elements developed in Game·Tel. Afterwards, Sections 4 and 5 describe how the pertinent IMS specifications were adopted and implemented in Game·Tel. Section 5 presents the main results from the validation pilots. Section 6 provides an overview on related work. We end the paper with some conclusions.

2. IMS Integration Specifications

The IMS Global Learning Consortium (IMS Global Learning Consortium, 2012a) is a non-profit organization devoted to the development and promotion of learning technology standards and specifications. Specifically, the remote invocation of learning applications is the focus of an intense research, which is endorsed by the existence of recommendations such as IMS Learning Information Services (IMS LIS) and IMS Learning Tools Interoperability (IMS LTI).

2.1 IMS Learning Tools Interoperability

IMS LTI is a standard to allow remote tools to be integrated into a learning environment (such as an LMS). The basic use case of this specification is to allow the seamless connection of web-based, externally hosted tools, to a learning environment. Eventually, users are provided with access to the remote tools as if they were available in the same server than the LMS. IMS LTI proposes a web protocol and an API to support this integration, without having to develop and maintain custom integrations. In this way, IMS LTI is an important step ahead in the field of distributed e-learning systems, as long as it allows expanding the functionalities of the LMS with the aid of external tools.

The LTI specification has been developed following a two-step effort. Initially, it published a reduced version of the specification named as Basic LTI (McFall and Neumann, 2010). This version was just focused on the launch of the remote tools and on the provision of user access to such tools in a seamless and authenticated way. More recently, LTI version v1.1 was published (McFall and Neumann, 2012) with the whole specification dealing with new issues (see Figure 1).
The new aspects covered specially the outcomes transfer from the tools to the main system based on LIS Basic Outcomes.

The LTI specification uses some specific terminology as it is represented in Figure 1. The learning environment is referred to as the “Tool Consumer” (TC) as it “consumes” the tool. The external tool is called the “Tool Provider” (TP) as it “provides” the tool that is going to be used from the “consumer”.

IMS LTI is included within the IMS Common Cartridge (CC) reference model (Kahn et al., 2008). This model describes how the access to web-based tools can be embedded into cartridges. IMS CC also integrates other well-known IMS standards related to metadata (IMS Learning Object Metadata) (IEEE, 2002), and questionnaires (IMS Question and Test Interoperability) (Bacon et al., 2006). These three specifications are aimed to support content reusability, in contrast with the interoperability issues where we are focused on this paper. In conjunction they provide a comprehensive framework both for reusability and interoperability.

2.2 IMS Learning Information Services

IMS Learner Information Services (LIS) (Feng and Lee, 2010) is a specification to manage the information exchange among a LMS and external applications in charge of student, staff and course information management. This specification can be implemented using web services based upon SOAP/HTTP or using LDAP (Lightweight Directory Access Protocol). The specification is structured in the following components:

- Person Management Services (PMS)
- Group Management Services (GMS)
- Membership Management Services (MMS)
- Course Management Services (CMS)
- Outcomes Management Services (OMS)
Currently, IMS LIS is fully integrated with LTI and data exchange between a TC and a LIS Service is possible as well as between the latter and a TP. Thus, using the LIS Basic Outcomes service it is possible to send the student grades to a LIS Service, read the results or delete them. Full data exchange among the components is possible.

3. Game·Tel System and Architecture

Game·Tel provides the functionality of a typical LMS following a modular web-service-oriented approach (see Figure 2). The central component of the system is the Game·Tel Web Server. This component provides the main user interface for each of the roles identified. It also acts as the integration hub for the other components. This component can act as TC in accordance with IMS LTI. In relation with other components, the Game·Tel architecture involves the integration of several systems that existed before the project was initiated:

- The <e-Adventure> platform is a key component of the platform. It is a framework providing an authoring tool and player for game-based educational environments. This has been integrated making the <e-adventure> system IMS-LTI compliant acting as a TP.
- The User and Course Management (Administration) component provides the functionality to manage course data, user data and membership data through a set of web services. The development of this component has been based on the IMS LIS specification. We did not adopt IMS LIS fully, but just the services required for the project.
- The PoEML Engine component provides a set of web services and a database to manage lesson plans (Perez et al, 2010). Lesson plans are organized in accordance with the PoEML specification (Caeiro, 2007; Caeiro et al, 2007). PoEML indicates how to define learning units that can be aggregated at different levels including activities, contents and resources (e.g. learning tools). In addition, it is possible to specify the conditions under which a content/unit is graded by a learner or how learners get access to some unit/content. This supports management of lesson plans. This component facilitates both the authoring of the models as well as their enactment.

![Figure 2: General Game·Tel Architecture](image-url)
In addition to the previous components we connected to Application Servers that can provide resources to be included in lesson plans. These resources can be offered from third-party (external) servers acting as LTI TPs or not. Based on IMS LTI the following resources have been integrated: a wiki (MediaWiki), a blog system (Wordpress) and Game∙Tel games (for PC and TV). Other kinds of resources, such as YouTube videos and SlideShare PowerPoint presentations, were also integrated but not following the LTI specification.

The Game∙Tel Web Server includes the presentation layers of the system to support the interaction with final users: administrators, learners and course authors. This component acts almost exclusively as a user interface, as long as the functionalities are provided through the use of Web services to the integrated systems previously described. The following user interfaces are available (see Figure 3):

i An administration interface to enable the operation of the administrator. Basically, this interface provides access to the User and Course Management Component. It also accesses the PoEML Engine in order to initiate the authoring of lesson plans, to create course offerings and, finally, to create instances of existing ones. The latter involves the assignment of learners to concrete instances, in such a way that each lesson plan instance is bound to one learner.

ii A course authoring interface that enables the definition and modeling of lesson plans. Figure 3(ii) includes a capture of the selection of a game as part of the lesson plan. The central part of the figure is the user interface of the tool repository where <e-Adventure> games are stored. It shows the list of available games that can be selected. In addition, the bottom of the figure

![Figure 3: Some captures of the Game-Tel system in action: (i) Administration; (ii) authoring tool while selecting a game for a course using the integrated <e-adventure> tool; (iii) learner interface for TV devices; (iv) learner interface for a PC browser while the student is playing a game.](image-url)
shows how it is possible to identify three slides that allow the selection of the lesson plan elements (units, content and resources), their preview in the same way that a learner will do, and the establishment of access constraints to this resource in accordance with the performance in other course activities.

iii A specific course player interface for TV, which supports the delivery of lesson plans to learners through a TV device. This has been designed to facilitate the use of a TV remote control device.

iv A course player interface that supports the delivery of lesson plan instances to learners. This is achieved by providing and updating the instances maintained in the PoEML Engine.

These last two interfaces have been developed satisfying some accessibility requirements to facilitate their use by people with disabilities.

4. Integrating with External Tools using IMS Basic LTI

4.1 Authentication and Access

IMS Basic LTI uses the OAuth (OAuth, 2012) protocol and Single Sign On (SSO) to encode the messages interchanged between TC and TP. OAuth is an open protocol that allows users to authenticate using APIs of several companies. OAuth requires a shared secret key to sign the messages. The key is transferred in each message, together with a signature based on the key.

The aim of this authentication method is to get access to the protected resources without requiring users to introduce their user name and password for each resource. This is a bit different from the typical OAuth scenario as users are not required to maintain a personal account in the protected resource. The system acting as TC has its own user account in the TP and authenticates itself. Later, it provides access to TC users by following the OAuth protocol. Our central Game•Tel Web Server has to generate a signature that identifies the user based on a set of tokens provided from the remote tool.

The typical OAuth scenario involves three components: a resource that belongs to a user (Service), a system that wants to access to such resource (Consumer), and a User that provides access to the system to the resource. The authentication is performed using two types of tokens: Request Tokens and Access Tokens. The first guarantees that the User authorizes the Consumer to send operations on her/his name to the Service. The second allows the Consumer to execute operations in the name of the User over the Service. These tokens are unique for each user and resource.

In our scenario OAuth is used to provide a SSO facility, as it is shown in Figure 4. The messages 3-6, not required with SSO, are shadowed. This authentication is transparent for the final user, because s/he just introduces her/his login and password when access to the central component, but not to each remote tool.

4.2 Data Interchange

In December 2010 we performed the integration of MediaWiki and the <e-Adventure> game repository in the Game·Tel platform using IMS Basic LTI. At that time, IMS LTI was not published and the data interchange between the TC and the TP was not specified. Then, we decided to use Simple Outcomes (Severance, 2010) to perform the data transfer after the authentication. Simple Outcomes is a part of the IMS LIS specification that describes how to store students’ outcomes and performance. Now, Simple Outcomes has evolved and it was integrated in the IMS LTI specification with the name Basic Outcomes.
Simple Outcomes has been used to enable us to transfer the results generated when an <e-Adventure> game is finished to the central Game•Tel Web Server. Later, those results are transferred to the PoEML engine in order to update the corresponding lesson plan instance. The process is as follows (see Figure 5): when the user accesses the tool the TC sends to the TP the tokens to perform the authentication. When the user is authenticated, the TC sends some common info to the TP, such as user name, user e-mail address, course name, etc. Table 1 shows a detail of
some of the fields that can be provided from the TC to the TP. The operation of the TP can depend on the value of these fields. For example, MediaWiki uses the context-label field to distinguish between different wiki instances, and the value of this field is used to name the wiki. In this way, the creation is facilitated of as many instances of a wiki as required.

The TC also sends to the TP the call-back information. This call-back information includes the URL where the game results should be submitted and the id of the user in the TC. In this way, when the user finishes the tool (the game in our case), the TP returns the result info to the TC. This is done by issuing a POST request to the specified URL with a set of value-key pairs including relevant information.

In Game•Tel, the games return the values of a set of variables that were defined by the game’s author. This information can indicate if the user has finished the game with success or failure, the time to complete it, etc. To support the specification of variables in a free way the <e-Adventure> game authoring tool was modified. In a similar way, games were also modified to support the

<table>
<thead>
<tr>
<th>Field Id</th>
<th>Description</th>
<th>Possible Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>context_id</td>
<td>Identifies the frame containing the linked resource</td>
<td>1111111 ABCD</td>
</tr>
<tr>
<td>context_type</td>
<td>Identifies the type of context</td>
<td>Section Lesson</td>
</tr>
<tr>
<td>context_title</td>
<td>It is recommended an informative text line</td>
<td>“Design of software”</td>
</tr>
<tr>
<td>context_label</td>
<td>A tag for the context. It must be short</td>
<td>Software</td>
</tr>
<tr>
<td>Launch-presentation-locale</td>
<td>Language, country defined with IETF</td>
<td>See <a href="http://www.rfc-editor.org/rfc/bcp/bcp47.txt">http://www.rfc-editor.org/rfc/bcp/bcp47.txt</a></td>
</tr>
<tr>
<td>launch_presentation_document_target</td>
<td>It informs the browser about the location of the TC</td>
<td>Frame iframe window</td>
</tr>
<tr>
<td>user_id</td>
<td>Identifies the user uniquely</td>
<td>000a8345 AAAA23</td>
</tr>
<tr>
<td>user_image</td>
<td>It includes the URI of a file with a image</td>
<td>http://….</td>
</tr>
<tr>
<td>roles</td>
<td>User role in the tool</td>
<td>Instructor Learner</td>
</tr>
<tr>
<td>lis_person_name_family</td>
<td>Surname of the user</td>
<td>Míguez Smith</td>
</tr>
<tr>
<td>ext_ims_lis_basic_outcome_url</td>
<td>It includes the Simple Outcomes listener URI</td>
<td>http://…/simple_outcomes_listener.php</td>
</tr>
</tbody>
</table>

Table1: Some of the data fields provided by the TC to grant access to a user in a TP
delivery of variables including their name, type and value. First, this info is sent from the game (an applet) to the TP (a PHP application). Then, the TP includes Basic LTI Simple Outcomes fields (received previously from the TC) and sends a POST to the TC listener. The TP (actually an <e-Adventure> game repository) was made ad-hoc for this project and it is hardcoded, but it supports any number of variables.

A specific issue at the time of this development was that a proper field to send the variable type had not been defined in Simple Outcomes. In the case of Game∙Tel this is required as the data sent from the TP (the game) to the TC (the LMS) includes several items (e.g. the final score, the number of attempts, the duration of the last session) whose type needs to be identified in order to be properly managed by the LMS. Due to this field purpose modification, the TC Basic LTI Simple Outcomes integration of <e-Adventure> games can be considered as hardcoded, but it is based on an application-neutral data transfer code suitable for any kind of application, also built into the LMS. The resulting processing is specific for each application, but the Game∙Tel course authoring and delivery tools are prepared to show and process any number of variables. The course author just needs to indicate the variable name to get access to the game results. Variable names and types can be obtained from the <e-Adventure> TP. In Table 2 some of the Simple Outcomes fields sent by the TP to the TC are shown.

The current 1.1 version of LTI (which proposes LIS Basic Outcomes) allows sending, retrieving and removing from the TP a single result, which must be necessarily a string character with a number ranging from 0.0 to 1.0. In our case there is a need to transfer multiple values with their types clearly identified as stated above. The business logic of the games included in Game∙Tel requires this multiple value transfer at the start and end of the game. This means that the retrieval of data during the session by the TP, which is feasible in LIS Basic Outcomes, was not implemented in our solution.

5. Integration with an IMS LIS Administration System

Based on the needs of the Game∙Tel project, and in the adoption of the PoEML engine to support the management of lesson plans we developed a specific administration component that involved a subset of the LIS specification: the Course Management Service, Person Management Services and Membership Management Services. These modules were provided according to the data structures defined in the LIS specification. The main element not included was the Outcomes Management Service, because it was already provided and required by the PoEML engine (Pérez-Rodríguez et al., 2010). The LIS services were used through Web Services (see Table 3).
5.1 Course Management Service

The courses are represented in a two-fold way. For each course there is a Course Template (CT), which contains the original course (or pattern) that will be generated by the author in the PoEML lesson plan authoring tool. The information maintained in this course management service includes data such as title, description, prerequisites, topics, PoEML identifier, etc. The information about the course structure and contents is maintained in the PoEML engine. The PoEML identifier acts as a unique identifier in both systems.

Each course can have multiple “copies” in which students can be enrolled, called Course Offerings (CO). Then, there can be several COs available for the same course. The COs contain information regarding the deadlines for registration, start and end of the course, maximum and minimum number of learners, and so on. Similarly to the previous case, each CO is related with a PoEML course instance.

The status information of both the CTs as the COs is stored in tables. This information in turn determines the visibility of each course for users, when students can be enrolled in a CO or the authors can be working in the authoring.

5.2 Membership Management Service

This service relates each CT to an author, and every student with the COs in which s/he is registered. From this info, user gets access to the PoEML courses and course instances. In this case we have simplified the structure of the LIS tables because many data included in the specification were not required for the project. Nevertheless, we left open the possibility of completing the data structure according to specifications in the future if necessary.

5.3 Person Management Service

As in the previous case, this service has been partially implemented in accordance with the LIS specification. In this way, we have used the tables needed to represent the user model required by PoEML distinguishing between learners and authors. We have also introduced some elements to enable the integration of a recommendation system and the connection of the users with the social network included in the project.
6. Experiences

The Game∙Tel system has been tested with real users to validate its usability, completeness and the provided functionalities, including access to external tools. On the one hand a first group of eight teachers tested the provided authoring tools. On the other hand, two groups of students (ten with disabilities and five without disabilities) tested the LMS itself in a set of learning sessions and using several devices.

Teachers were requested to create courses using Game-Tel that integrated both games and external tools and applications. Students, in turn, were required to test the previously developed courses in a series of learning sessions.

It must be said that accessibility has been tested using TAW tools (CTIC, 2012) to get W3C WCAG 1.0 compatibility, but had some problems due to use of JavaScript and AJAX technologies. These issues were reflected in user evaluations.

Results were gathered through a set of questionnaires where users had to score from 1 to 5 the assertions presented to them (Ortega and Pérez, 2010; Anido, Fernández and Manso, 2010). The information gathered in the pilots showed that the objective to achieve complete transparency in the integration of external tools was achieved. This was the case for most applications. In the case of course visualization, the data exchange provided by Basic LTI was enough to cope with all the communication requirements. Nevertheless, in the case of the authoring pilot, the lack of some issues in the LTI specification was noticed, such as the possibility of integrating collaborative multiplayer games, the management of game sessions, etc.

7. Related works

The development of solutions that allow e-learning systems to integrate external tools is a field that has gained a lot of attention from the research community. There are many proposals in this area that basically differ in their degree of generality (i.e. the range of integrated tools and the level of integration).

IMS maintains a web page with information about LMSs compliant with the IMS LTI “Tool Consumer” features and also tools that can act as “Tool Providers” (IMS GLC, 2012b). Some well known LMSs such as Sakai, Moodle or ATutor can act as TCs. In addition, there are several tools that can be offered as TPs. During recent years, several European and USA projects were very focused on this field:

• The Library of Labs Project (LiLa) (LILA, 2012) is an initiative for the mutual exchange of and access to virtual and real laboratories accessed via Internet. LiLa provides a portal granting access to virtual and real laboratories, along with services such as a scheduling system or connection to a 3D collaboration environment. Nonetheless, LiLa only includes ad-hoc solutions for the access to (remote or virtual) laboratories: each institution belonging to LiLa has developed their own technology to access its laboratories. Rather than a particularity of LiLa, this technological heterogeneity was a distinctive trait of the access to laboratories.

• iLabs (iCampus, 2012) at the MIT, which has become the de-facto standard laboratory to access technology. However, a common point of all these technologies is that they lack means of controlling and supervising the experiments of the users.

• The ROLE (Responsive Open Learning Environments) project (Govaerts et al, 2011) is working with OpenSocial to provide PLEs built on gadgets that can be combined and interoperable with
the existing ones in the iGoogle platform.

- Similarly, the iTEC(innovative Technologies for an Engaging Classroom) project (iTEC, 2012) is also working on the idea of integrating gadgets available in the Web to support user activities.

In addition, most current e-learning systems such as Moodle (Blanco et al., 2011; Moodle, 2012a) or Blackboard (Blackboard, 2012) have capabilities to extend their own functionalities. Moodle proposes the so-called “extensions” (Moodle, 2012b). Blackboard proposes the Proxy Tool (Kroner, 2010), which aims to develop a framework that can be used by a Blackboard system in order to invoke remote tools. Wookie (Wookie, 2012) was based on the integration of widgets developed in accordance with W3C and Open Social standards. Finally, another project to integrate external third-party tools in e-learning systems is the one developed for LAMS (LAMS, 2012). LAMS allows the installation of plugins to use (and be used from) external systems.

This section shows that these specifications are already, at least to some extent, widely available in common LMSs. The work presented in this paper can be seen as a hands-on experience on the actual use of these existing specifications to meet the requirements of a particular system such as Game•Tel.

8. Conclusions

The Game•Tel project aimed at providing a holistic solution for e-learning environments. The project has dealt with accessibility issues, multi device environments, multi-purpose contents and ad-hoc configuration of LMSs through the integration of external tools and applications. This paper analysed the latter aspect including the alternative approaches and specifications researched, the architecture proposed and the implementation of the selected integration/communication specifications.

The specifications followed to integrate external tools into existing LMSs come from the IMS global consortium. IMS has been one of the key players in the learning technology standardization process since its very beginning in the late 90s. It has produced dozens of specifications and reference models in this area, some of which have become de-facto standards due to their wide acceptance among the community.

In the case of Game•Tel the core specifications used were IMS LIS and IMS LTI. The use of the recommendations included in these allowed us to provide a complete integration between an external application and the core Game•Tel LMS. The user perceives the different tools as a monolithic system, being hard for her to distinguish which application belongs to the core LMS and which were taken from an external party.

The integration of external applications provides obvious benefits for existing LMSs. It is possible to add new functionalities, not provided by the original LMS, through the integration of new external tools providing such functions. It is also possible to replace existing modules in the original application with those providing similar functions from outside the LMS. Thus allowing to easily update some functionalities of the LMS without the need to install a new version of the whole LMS (e.g. the IMS LIS allows for instance to enhance the user/course administration of the LMS facilitating the integration with the core administration tools at the educational institution).

On the negative side, we have to mention the slowness of the production process for these specifications. Although IMS is quite an active and agile consortium that produces the specifications in a reduced time frame, this was not the case for IMS LTI. The first version of the specification (IMS
Basic LTI was published in 2009. The first draft of the complete specification was not available until December 2011. This meant that those implementing IMS LTI, like the Game∙Tel team as explained in this paper, needed to take their own decisions on those aspects not covered by the published basic version of the specification. A particular aspect where we needed to take our own decisions was on the procedure to return data from the integrated games to the LMS. This aspect, like many others not covered in IMS Basic LTI, are now covered in the new version of the complete specification. Taking as a reference the experience with previous IMS specifications, it is expected that its recent publication will be the starting point for a wider dissemination and acceptance of the IMS proposal to integrate and communicate LMS and external tools.

IMS specifications are also based on practical experiences of their previous versions. Insofar as this is concerned Game-Tel contributes through the implementation of their previous versions, which were tested in practice by real end users. Additionally, the Game-Tel consortium was the main promoter of the creation of a working group within AENOR CTN71 SC36 (the Spanish body for Learning Technology Standardization) to develop a standard for the communication between interactive applications based on the current IMS specifications and the results gathered in Game-Tel.

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Mario Manso-Vázquez received the MSc degree in telecommunication engineering in 2007 at the University of Vigo, Spain. He has worked as software engineer and graphic designer in several companies. Nowadays, he is hired as a researcher in the University of Vigo and he is interested in PLEs, e-learning and care systems for kindergartens. He has participated in Game-Tel e-learning project as software developer and interoperability manager. In addition to his academic and professional interests, Mario is a skilled musician and plays in several pop and local rock groups.

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