

# Cross-Curricular Approach to Robotics in Interactive Museum-Pedagogy Environment

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**Abstract**— In the scientific field of Museum Pedagogy, a construction and its interpretation, constitute the signifier and the signified for the educational procedure. It is a common sense that the presence of new technologies, by tangible or virtual means, should contribute in a useful and functional manner in order to preserve the museological structure respecting educational aims without underestimating the value of the museum exhibits. Sometimes it is common knowledge that the technological and the interactive museum exhibits could distract the visitor from cancelling the possible experiential learning. The implementation of the project “Ancient Greek theater” showed that the exploitation of robots in museum activities can contribute to the achievement of museum-pedagogical aims. The cross-curricular design is an important factor for the balance between social-humanities and technological studies. Also the intuitive control and the playful character of the interactive environment create and support engaged and experiential learning, which lead to better comprehension.

**Keywords**— Cross-curriculum, Educational Robotics, Interactive Robots, Learning Environment, Museum-Pedagogy, Edutainment,

## I. INTRODUCTION

In the scientific field of Museum Pedagogy, a construction and its interpretation, in the museological planning, constitute the signifier and the signified for the educational procedure. The interpretation of the museum exhibits is a complex procedure and the educational and museum pedagogical structures compose the appropriate means to bridge the gap between the museum exhibit and the museum visitor.

The polysemy of the museum exhibits is formatted by the interconnections of the external shape with the cultural symbols, ideals and the values which the exhibits represent [1]. When the prior knowledge, the empirical, cognitive and the aesthetic background of the museum visitors are taken into consideration in combination with the social changes as they are reflected in the museum exhibits [1], [2] could make the interpretation complete, unprecedented and unique.

## II. MUSEUM-PEDAGOGY

### A. Learning and Interaction

The museum constitutes a learning, communication and entertainment environment. In the frame of the educational structure planning in a museum-pedagogical program, the concept of the experiential learning is disposed as a possible strategy bridging the gap between the transmitter and the

receiver and creating accessible the complete interpretation of the museum exhibits. The museum visitor learns by doing, raising his interest for a creative expression. Through interactive methods like texts 'dramatization, drama and theatrical plays with the rest members of the museum visitors' group, having as a springboard the museum exhibits, the social interaction also could be enhanced [3]. The concept of the interaction consists of animation as a catalytic factor and motive which could elect the interpretation and the museum exhibits' learning. In this way knowledge is constructed gradually while the museum visitor participates directly in the experiential procedure.

The interaction could also be the social interaction between museum visitors as members of a whole museum group and determines for a thorough accessing of the museum exhibits, the museum research and the possible results which could be formatted through that experiential procedure [4], [5]. An important and functional point which could be part of an interactive planning is the feedback. Providing the museological planning with feedback is taken into consideration the fact that the direct springboard is the obtained cognitive background in the museum space, the experiential background of the museum visitor and as well as the possible reproduction of all this obtained information in order to obtain a further research and a continuous learning [7].

### B. Interaction through technology

Initially, technology contributes in the digitization of the museum material collections, enhancing the necessary and appropriate points in order to preserve the documentation, the projection and the research with direct access in the wide public [8]. Terms which are stated such as digital, virtual and cybermuseum determine a part of the whole wide frame of technological contribution in a museum organization.

Taking into consideration the digitization of the museum material collections as it is projected through the interface of a digital museum and as it is created in a virtual museum, it offers the opportunity in a museum visitor-user to immerse in a virtual tour and in the cyberspace of a cybermuseum where a possible visual interaction takes place and a visual conceptual experience is feasible [9], [10].

Other interactive forms are through mechanisms such as wireless sensors, audiovisual devices-speakers/projectors (information overlay in smart rooms) where technology is part of the museum space but also the specialized interactive narrative with smart clothes in the form of a jacket or a vest

with a small embedded computer and a lightweight headmounted display or glasses (where the technology is part of the museum visitor) providing the visitor with the opportunity to recall information from his experiential cognitive background in order to create a unique personal narration [11], [12].

In the game interaction, the museum visitor has the chance to interact with virtual or real museum exhibits and constructions in a playful manner. The game is chosen as a method which could be a useful springboard under an educational and museum-pedagogical point of view accessible to the museum exhibits through technology [6].

Finally, the most frequent form of robot interaction in museums is the robot – guided tour, which either guides the museum visitors or performs the commands which are being given by the visitor [13], [14], even with the support of augmented reality [15].

In order to create user friendly and functional activities, the robots’ operation should be achieved through intuitive and human based interactive operation [16], [17].

### III. PROJECT “ANCIENT GREEK THEATER”

Based on the above museum-pedagogical principles about interactive learning activities, but also on research results about proper robotic lesson construction [18], [19], cross-curricular activities constitute a meaningful learning approach. The “Ancient Greek Theater” is a cross-curricular project, which aims to offer a study environment on Humanities and Technology topics, as shown in Table I.

TABLE I  
CROSS-CURRICULAR TOPICS

subject	topics
Culture,	comedy and tragedy - spiritual values

Sociology, Literacy, Art, Geography	through ages politics and Democracy religion and ancient gods apparel & life habits ancient Greek theatres at the Mediterranean Sea
Sciences, Technology	acoustic marvel (filter and reflector) optics (theatre = viewing place) stable construction - static mechanical manipulators, cranes and other artefacts dimensions and analogies

#### A. Operation and Scenario

The Ancient Greek theater project (Fig. 1) is a representation of the ancient theater enhanced by robots. The involved robots automate the theater’s functions (robot-crane), but also interact with the user as actresses (robot-dolls). Two cameras are being used to recognize the body motions of the participant students, who wear blue and yellow theater suits. Every motion of the student with blue suit causes the corresponding motion to the blue robot actress. The same operation of distance control works also for the yellow pair (student-actress and robot-actress). When the students manage to bring the robot-actresses in front of the scene, with proper motions, then the robot-crane brings a god onto the stage from above.

The scenario of the activity is based on the play "Iphigenia in Tauris" by Euripides. It is a tragedy that was written between 414 and 412 BC. The work unfolds in scenes "in Tauris" where priestess Iphigenia offers libation to goddess Athena and begs for help.



Fig. 1 Two students participate in the activity

The author, Euripides, at this point uses the story telling technique “Deus ex Machina” (god out of the machine), at which a seemingly inextricable problem is suddenly and abruptly solved with the contrived and unexpected intervention of a god. In ancient Greek theater this was carried out by the use of a crane which was bringing an actor-god onto the stage from above (Fig. 2).

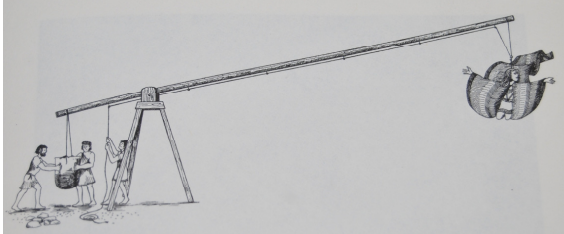


Fig. 2 Crane was used to bring actors (gods) onto the stage

### B. Construction

The project has been constructed according to ancient theater’s analogies. Greek theater buildings were called a Theatron. The theaters were large, open-air structures constructed on the slopes of hills. They consisted of three principal elements: the Orchestra, the Skene (stage), and the Audience. The centrepiece of the theatre was the orchestra, or "dancing place", a large circular or rectangular area. Behind the orchestra was a large rectangular building called the skene. It was used as a "backstage" area where actors could change their costumes and masks, but also served to represent the location of the plays. Rising from the circle of the orchestra was the audience. The audience sat on tiers of benches built up on the side of a hill.

In “ancient Greek theater” project, three robots have been involved. All robots are constructed with the use of Lego NXT Mindstorm educational sets. The two robots represent the priestesses (Fig. 3, 4) and the third materialize the crane “Deus ex Machina” (Fig. 5). In Fig. 4 we can see the mobile robot structure. It has three degrees of freedom: body straight movement, waist and hands rotation.



Fig. 3 Robot actress

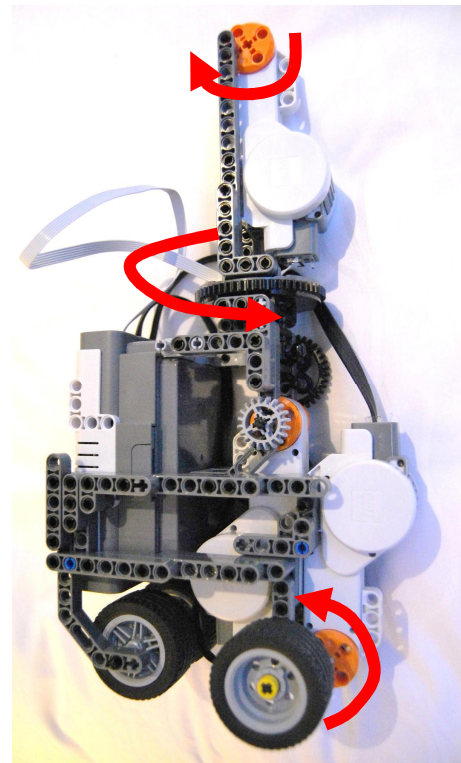


Fig. 4 Robot actress – 3 degrees of freedom

The robot-crane (Fig. 5) should be able to hang and transfer the god in any place above the stage. For this reason the architecture of an industrial robot arm has been adopted. The PUMA Unimation robot type (Fig. 7), is a 6 degree of freedom articulated robot, popular in industry and research institutes. The theater’s crane implements the first three joints and links of PUMA robot (Fig. 6). The three first joints’ axes, give three degrees of freedom (waist, shoulder, elbow), which means free positioning in the space (independent X,Y,Z coordinates) (Fig. 8).



Fig. 5 The robot crane “Deus ex Machina”

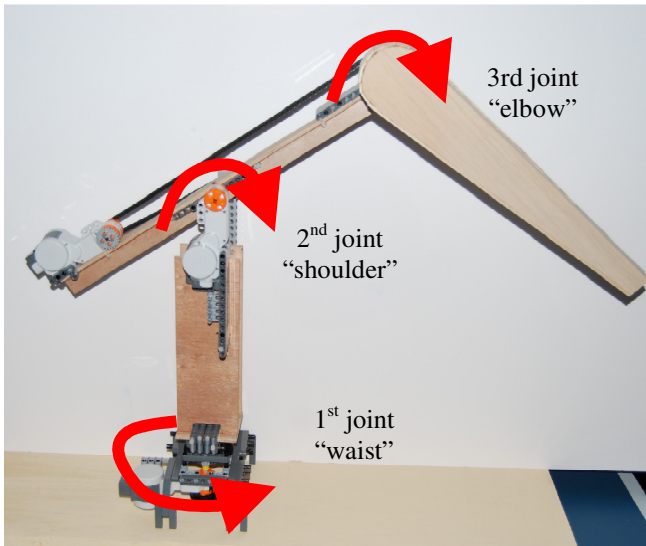


Fig. 6 The robot crane - architecture

The system encompasses two NEXTCam v 3.0 Midsensors (Fig. 9). These cameras support real time image processing for identification (up to 8 objects) and communicate directly with the I2C bus of NXT.

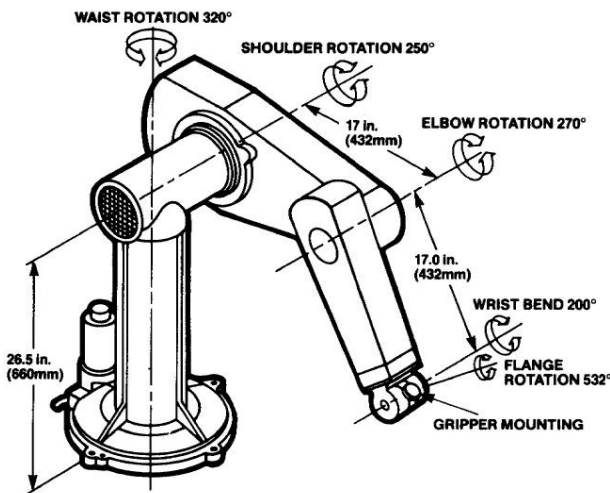


Fig. 7 Joints and rotation axes of PUMA

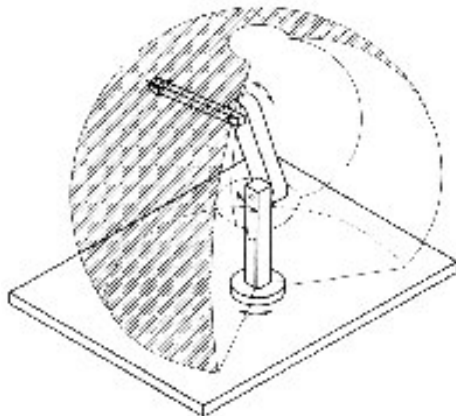


Fig. 8 Workspace of an articulated 3 DOF robot arm

The two cameras identify the bodies with the blue and yellow kirtles (clothes). The coordinates of the body are then extracted and filtered. Based on this information a forth NXT calculates in real time the path of the two mobile robots (dolls) and in this way the system follows the movements of the users.

The four NXTs, that the project encompasses, communicate with Bluetooth technology.

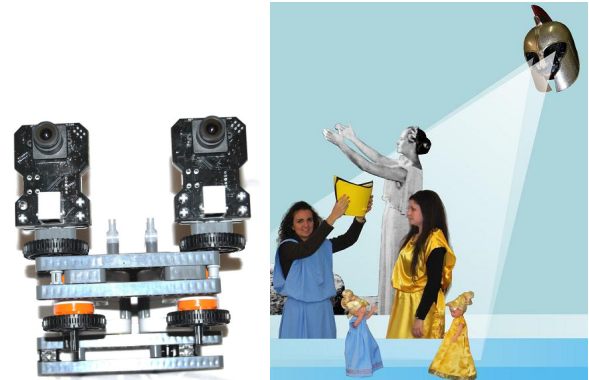


Fig. 9 The two NEXTCams and the vision system

#### IV. LEARNING GOALS

The “ancient Greek theater” project implements many issues of the robotics technology which can be considered as the learning goals in the Science and Technology curriculum (Table II). The projects includes four microcontrollers (NXTs), which are used in the control of mobile robots (the 2 dolls), in the control of a robot arm (the crane) and in the image processing and path creation (the eyes unit). All the 4 units collaborate and communicate, exploiting the Bluetooth ver. 2.0 capabilities of NXT. Control theory implemented in the closed loop control of the mobile robots, for the participant’s body motion following in real time.

The robot arm has been developed based on the industrial PUMA Unimation robot arm and implements three degrees of freedom motions (3 DOF), having the capability to reach any point in its working area. The project also uses position-rotation, distance and audio sensors, as well as two cameras.

TABLE II  
LEARNING GOALS AS TECHNOLOGICAL PROJECT

Robotics and Control	Cognitive goals
Robot design-construction	Industrial robot architecture (PUMA-Unimation) Balanced robot arm Mobile robots Cooperative robots
Control	Control theory – position control Closed loop feedback
Electronics	Optical sensors Position sensors
Communication	Bluetooth ver. 2.0 Multiple communication (4 NXT interaction)
Signal Processing	Real time image process Motion detection & following

	Multiple objects' motion following 3D view capability
Intelligence	No preprogrammed motion Real-time motion creation based on user's movements Body gesture recognition

## V. CROSS-CURRICULAR GOALS AND LEARNING APPROACH

As mentioned above, the “ancient Greek theater” offers a learning environment for the students, to work on cultural (play spiritual values), sociological (politics, life habits, religion and ancient gods), literary (drama, comedy), artistic (scenery, apparel, masks), geographical (ancient theatres at the Mediterranean Sea) topics. This cross-curricular approach has the advantage of the global view and also facilitates the investigation of topics connection.

The presentation of the project is based on active participation of the students (Table III). Students assume the role of actor of tragedy, wearing ancient Greek tunics, holding ancient religious object (amphora) and following the Greek ancient theatrical ritual, in front of the stage and the “viewers” and provoke the “Dues ex Machina”.

The presentation of the cultural and technological aspects of the ancient Greek theatre, is been achieved not in a passive way, in which the robots acts and the people just watching. In this performance type presentation, the person gets involved in a dialogic relation with the subject and the robots become the tools that support a cognitive process. The prevalent idea in the contemporary research of museum-pedagogy considers as major factor the personal engagement in a dialogic process [18]. Students take advantage of the dynamic environment of the robots, the “hand on” capability, the user driven action, the realistic and dramatised scenario and scene, to impart the cultural ethics, the literature aspects and the every day habits (like apparel) to the participant.

The participants have the opportunity to integrate with their heroes through the man-machine interaction experience of the ancient Greek tragedy. The two participants are asked to represent one of the most critical stages of the play (tragedy), in which two priestesses make supplication to the goddess. Specifically, Iphigenia with the escort of another priestess, beg the goddess Athena to help her come out of the moral dilemma. This learning approach and the project context also ensure that the impact of traditional gender roles are neutralized, promoting girls' engagement [18].

The movements, which are described by the project and participants are asked to implement, are natural, human, and realistic, supporting intuitive operation. The motion of robots is driven by the participant (through cameras usage), but also the robots shows to the participants if their effort has positive evolution (raising the hands, appearing the god out of the machine, etc), offering the necessary feedback. The whole interaction system relies on wireless communication and the cameras which are placed inside an ancient helmet, making the scene more natural and aesthetically beautiful. As no remote control used or any inelastic pre-programmed robot movements, the presentation gets deep interactive format. Also, by a faithful representation of the scene and getting

experience through the role playing game, we have Edutainment framework. The achievement of edutainment is very important, since it combines education with entertainment, as participants come in direct contact with the ancient culture and understand the ancient ethics and principles advocated by the project.

TABLE III  
LEARNING APPROACH CHARACTERISTICS

Aspect	Approach
Presentation - Participation	Dynamic - “Hands on” type User based Realistic Scenario Theater's scene - Dramatized presentation Cultural ethics presentation Literature presentation (myths, tragedies) Apparel presentation
Man-machine interaction	Intuitive control Natural motions User friendly No remote control device
Understanding - Cognitive	Engaged learning Role playing game Accomplishment of objectives Experiential type comprehension Creative type comprehension Edutainment

## VI. EDUCATIONAL IMPLEMENTATION

Students from elementary and junior high school have participated in educational activities, based on the “Ancient Greek theater” project (Fig. 10). In the beginning, a museum-educator presents the ancient Greek theater topic, through discussion with students. This stage aims also to extract students' prior knowledge, in order to design and adapt properly the following activities. Then the students participate in pairs, trying to represent the ancient tragedy, by telling the story dialogues and wearing theater masks and suites. Their steps and movements aim to drive the robot actresses.

Exploiting the intuitive manipulation of the robots, students show a fluent operation of the system, with no orientation or kinetic problems. They were able to focus on the play and to cooperate with their teammates, in order to represent the play scene successfully. In this way, as they expressed, they learned the humanity topics of the project, in a playful and edutainment manner. In this environment they show continuing interest about topics, which in general have lack of participation in a typical classroom course.

Regarding the Science and Technological issues, curiosity and robots' interactive response drive them to participate enthusiastically in the investigation of the relative aspects. At the end of the activities they were able to recognize and explain project technology and to compare and correlate it with other industrial or even every day technologies.



Fig. 10 Elementary students participate in “Ancient Greek Theater”

## VII. CONCLUSIONS

It is a common sense that the presence of the new technologies, by tangible or virtual means should contribute in a useful and functional manner in order to preserve the museological structure respecting educational aims without underestimating the value of the museum exhibits. Sometimes it is common knowledge that the technological and the interactive museum exhibits could distract the visitor from cancelling the possible experiential learning. Furthermore, the virtual or tangible technology representations sometimes are not able to transfer the meaning and the aims which are represented by the real exhibits and also they cannot replace the experience which could be obtained through the direct access with the real museum exhibits.

As the implementation of the project “Ancient Greek theater” showed that the exploitation of robots in museum activities can contribute to the achievement of museum-pedagogical aims. The cross-curricular design is an important factor for the balance between social-humanities and technological studies. Also the intuitive control and the playful character of the interactive environment create and support engaged and experiential learning, which lead to better comprehension.

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