

# Athens Journal of Sciences

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# Athens Journal of Sciences

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The current issue is the third of the ninth volume of the *Athens Journal of Sciences (AJS)*, published by [Natural & Formal Sciences Division](#) of ATINER.

Gregory T. Papanikos, President, ATINER.



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*A World Association of Academics and Researchers*

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- Acceptance of Abstract: 4 Weeks after Submission
- Submission of Paper: **19 June 2023**

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## The Effects of Sounds and Music on Cells and Organisms: A Promising and Developing Area of Research

By Claire Brun\* & Jean-Marie Exbrayat<sup>‡</sup>

*This review is based on recent publications about the effects of sound, and more particularly of music, on several aspects of physiology. It has been known for a long time that music has effects on the brain and on the functioning of different organs. In recent years, several publications also described specific effects of music on the physicochemical mechanisms in the other organisms, bacteria, plants and animals. These researches being rather disparate in the methodologies used and the results obtained, they need to be classified. In this review, we summarize the studies and attempt to explain the cellular mechanisms involved, by considering the properties of the plasma membrane and its links with the extracellular and intracellular medium. This field of research is currently in full expansion, but still requires further studies to understand and go further in the possible applications, the precise molecular mechanisms of effects of music still remain to be clarified.*

**Keywords:** *sound, music, plant, animal, unicellular organism*

### Introduction

Music is a complex acoustic and temporal structure, whose effects on biology are a hot topic. It has long been known that music influences mood and arouses strong emotions. Today, we are discovering the numerous effects it has on the brain and on organic functions. It is used in a care approach (music therapy) (Behzadmehr et al. 2020, Billar et al. 2020, Buglione et al. 2020, Bulut et al. 2020, Martin et al. 2020, Çelebi et al. 2020, Chai et al. 2020a, b, Cimen et al. 2020, Chan et al. 2020, Dai et al. 2020, Ernberg et al. 2020, Gamboa et al. 2020, Garcia Guerra et al. 2020, Giordano et al. 2020, Gogoularadja and Bakshi 2020, Guo et al. 2020, Howlin and Rooney 2020, Johnson and Elkins 2020, Köhler et al. 2020, Pérez-Eizaguirre and Vergara-Moragues 2020, Polascik et al. 2021, Saraogi et al. 2020, Usui et al. 2020, Wang et al. 2020, Zhang et al. 2020, Dunbar et al. 2021, Yang et al. 2021), but its influence on well-being goes beyond the human being (Sambraus and Hecker 1985, Hurnik and Johnson 1997, Kenison 2016, Bowman et al. 2017, González-Grajales et al. 2019, Kemp 2020). In fact, many studies have described the various effects of music on different organisms (Lemarquis 2009, 2021, Dhungana et al. 2018, Exbrayat and Brun 2019, Mayoud and Lemarquis 2019, Pulcrano and di Porzio 2021).

Music is a fundamental mean of communication, which developed and diversified over the millennia as human beings migrated around the planet (Wallin et al. 2000, Mehr et al. 2020, Savage et al. 2020). It allows people to share intentions

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and emotions. Power of music pass through the capture of musical sounds by auditory cells which record sounds, transform them into electrical signals which in turn reach the brain where they are translated into emotions. The neurophysiological mechanisms are better known thanks to the development of innovated methods (Zimmermann and Fermin 1996, Fettiplace and Hackney 2006, Ashmore 2008, Müller 2008, Rabbitt et al. 2010). Scientific evidences thus confirmed the long-praised medicinal virtues of music, such as neurostimulation and neuroprotection (Lemarquis 2009, 2021, Jones et al. 2020). But for a few years now, more and more publications have addressed the direct effects on non-auditory cells, a less obvious aspect of the effects of music (Lestard et al. 2013, Lestard and Capella 2016). The experiences performed by researchers present very disparate results. Whatever this great disparity, the study of the effects of sound and music on cells reveals the available possibilities to modulate cell physiology.

### **Evolution and Adaptation of Communication in the Animal Kingdom**

So that an organism could live, it is necessary that it communicates with other organisms and, in a broader sense, with the elements of the environment. Throughout its life, every organism is subject to many stimuli. In unicellular organisms, the single cell is equipped with receptors that register different types of stimuli acting directly on it. Some unicellular, prokaryotes or eukaryotes, are sensitive to molecules emitted by other individuals and react by synthesizing substances. They may also be sensitive to vibrations produced by sound and respond by producing molecules. For example, among unicellular organisms, volvox algae live in colonies of thousands of flagellated cells, able to move toward the same direction. All the cells contain a light-sensitive pigment that directs each cell towards it, and the perception of light allows a set of juxtaposed cells to move towards the same goal (Hallmann 2003, Ikushima and Maruyama 2007).

In sponges, jellyfish and polyps, a reduced number of cell types is observed and the nervous system is limited to a few neurons, or it is almost absent (Arai 1997, Moore 2006, Barnes et al. 2009). The perception of external signals exists however and allows oriented movements and responses adapted to the environment. As organisms become more complex, various sensory organs appear, in connection with the development of an increasingly efficient nervous system. The latter will allow a better adaptation of the organisms in their environment. Stimuli are then received by receptors of sense organs, and the nerve impulses are transmitted and interpreted by the nervous system.

For Humans, the five specific senses commonly known and already listed by Aristotle (384-322 BC), are touch, sight, hearing, smell and taste. In addition, there is a general sensitivity including mechanoreception, thermoception, nociception and proprioception.

There are also other types of senses in the animal kingdom directly related to the evolutionary level and the way of life of organisms. For example, fish and certain amphibian larvae have a lateral line which allows perception of water movements and hydrostatic pressure (Bleckmann and Zelick 2009). They also

have an ampullary organ (consisting of the ampullae described by Lorenzini in 1678) which is sensitive to low frequency electric fields and allows electrolocation (Roth and Tschardt 1976, Gibbs and Northcutt 2004, King et al. 2018). In lizards, snakes and caecilian amphibians, particularly well-developed vomeronasal organs are added to the classic olfactory organ (Badenhorst 1978, Billo 1986, Billo and Wake 1987, Døving and Trotier 1998). Finally, in some migratory birds, magnetoreceptors make the individual sensitive to the earth's magnetic field (Wiltschko and Wiltschko 2012).

### **Sounds and Music as a Communication Signal**

In the course of evolution, different mechanisms have been selected to allow animals to emit sounds and communicate.

Aristotle already indicated that fish could emit “vocalizations”. A significant number of studies confirm that some fish emit sounds and that their repertoire is surprisingly vast. So, sound is involved in a large number of behaviors related to reproduction, feeding or defense of the territory. The means of producing sounds are variable; they range from the air bubble released by the posterior part of digestive tube (in herrings) to chirping produced by the friction of two hard parts of the body: striated joint of the pectoral fins in catfish, pharyngeal teeth located at the level of the gills which squeak in *Haemulon plumierii*; some species can also use the swim bladder to emit sounds (Parmentier et al. 2016, Raick et al. 2018, Di Iorio et al. 2019, Huby et al. 2019, Bolgan et al. 2020). About 100 families of bony fish have been shown to be able to communicate acoustically. The same species can even produce several different sounds. Currently, the "vocalizations" of more than 200 species of fish were described in the Northwest Atlantic (Fish and Mowbray 1970).

Aquatic mammals such as Cetaceans also emit all kinds of sounds, vocally or not, allowing communication between animals of the same species (Payne 1984). Sonar is used by dolphins (Whitlow 1993). These animals emit sounds of varying frequencies to communicate or find their way in space. They use air sacs (Helmholtz cavities) to emit sounds at various resonant frequencies. When diving, dolphins store air in the lungs. They use their larynx to produce ultrasounds (Whitlow 1993).

Bats use echolocation to navigate and locate prey. They modulate calls of different frequencies according to the species, which allow them to perceive the distance of the prey or the obstacle by measuring the delay between emission of the call and echo. The perception of sound is carried out by a classical hearing system (Suga and O'Neill 1979, Moss and Sinha 2003).

In many species of birds, at the time of reproduction, the male utters a characteristic song using the syrinx, an organ made up of cartilaginous parts located below the trachea, unlike the vocal cords which are located above the trachea (Warner 2009).

These few examples show that the senses of organisms represent adaptations to living environment. Any response to the environment implies that stimuli such as molecules, vibrations, low frequencies, electric fields or light waves, are captured

at a membrane receptor, before a cascade of intracellular reactions leads to a response (Lim et al. 2015, Syrovatkina et al. 2016). The complexity of the sense organs observed in multicellular organisms is closely related to the development of the nervous system: from a simple network of nerve fibers in the mesoglea (mesohyle) of porifers and cnidarians, this system becomes more complex and centralized, allowing more elaborate behavioral responses. Table 1 summarizes the diversity of sound production mechanisms in animals.

**Table 1.** *Examples Illustrating the Diversity of Sound Production Mechanisms in Animals*

<b>Structures used in sound production</b>	<b>Mechanisms</b>	<b>Animals</b>
Use of resonant external substrate	Hitting a substrate	<b>Beavers:</b> slapping the tail on the surface of water <b>Spiders:</b> drumming during courtship sequences
Use of body structures	Clicking, snapping, vibrating	<b>Some insects:</b> wing vibrating <b>Cicadas:</b> vibrating a drum-like membrane (modified membrane located on the abdomen) <b>Fish (Sciaenidae):</b> swimbladder snapping <b>Birds:</b> beak clicking/grinding <b>Bats:</b> tongue clicking
	Rubbing body parts together	<b>Orthopterans:</b> stridulation by dragging the body part equipped with a scraper across an adjacent body part with a file-like structure <b>Fish (catfish):</b> stridulation by using the pectoral fins
	Vibrating a membrane in an air flow	<b>Birds:</b> tympaniform membranes vibrating (presence of a syrinx) <b>Amphibians, reptiles and mammals:</b> presence of a larynx containing vocal cords

### **Effects of Vibrations, Sounds and Music on Cells and Organisms**

In recent years, research has focused on the effects of music on various organisms in an attempt to understand how sound vibrations act at the cell level. Experiments have been carried out on cell cultures, in cancer cells, microorganisms, and on complete organisms, by testing different biological parameters (Lemarquis 2009, 2021, Dhungana, et al. 2018, Exbrayat and Brun 2019, Mayoud and Lemarquis 2019, Pulcrano and di Porzio 2021). Tables 2 and 3 summarize the state of the art about the positive effects of music in different organisms and non-auditory cells.

**Table 2.** *State of the Art About some effects of Music on Non-auditory Animal Cultured Cells*

Cultured cells	Effects of music
ST2 stromal cells C2C12 myoblasts	Suppression of mechanosensitive genes by audible sound stimulation
NIH3T3 fibroblasts NB2a neuroblastoma cells	No observation of suppression of mechanosensitive genes by audible sound stimulation, showing a cell type-specific response to sound
Human embryo	Improvement of fertilization rates
Cancer cell lines	Alteration of cell cycle and decrease in viability, but differences in response depending on cell line
Buffalo granulosa cell spheroids	Up-regulation of steroidogenic gene expression

Note: The key references are mentioned in the text.

**Table 3.** *State of the Art About Positive Effects of Music (Soft Rhythmic Music) in Different Uni- and Pluricellular Organisms*

Organisms		Positive effects of music	
Animal species	Domestic animals	Dogs	Increase in sleep duration
		Cats	Increase in approach behaviour
	Farm animals	Cows	Increase in milk production
		Buffaloes	Change in behaviour
	Race horses		Influence of emotional state
	Birds	Chickens	Increase in number of neurons and mean neuronal nuclear area
		Songbirds	Improvement in learning to sing
	Rodents		Improvement in spatial learning and reduction of anxiety-related behavior; increase in the body weight of pups
	Monkeys	Chimpanzees	Reduction in aggression
		Baboons	Decrease in heartrate
Elephants		Reduction of stereotyped behaviour	
Vegetal species	Herbaceous plants	Increase in germination, growth and development, disease resistance	
Unicellular organisms	Bacteria and yeast	Improvement in growth and antibiotic sensitivity	

Note: Choice of music, depending of the acoustic communication system of the species, is decisive to observe behavioral effect. In general, loud and inharmonious music tends to have a negative effect. The key references are mentioned in the text.

### *Effects of Vibration, Sound and Music on the Animal Cells*

The effects of electromagnetic waves on living beings have been studied for much longer than those of sound waves (National Research Council (US) Committee on Assessment of the Possible Health Effects of Ground Wave Emergency Network (GWEN) 1993, Cardinale and Pope 2003). Nevertheless, a number of studies suggest that emotions triggered by music can be particularly useful in relieving stress. Recent experiments show that different non-hearing cells respond to sound, the fluids contained in the cells being sensitive to pressure variations induced by sound waves. The mechanisms of cell growth or cell death affected by acoustic vibrations appear to be similar for all cell types, whether they

are auditory or not. The basic mechanisms could thus be common and universal (Zimmermann and Fermin 1996, Chan and Hudspeth 2005, Fettiplace and Hackney 2006, Ashmore 2008, Müller 2008, Rabbitt and Boyle 2010, Lestard et al. 2013, Lestard and Capella 2016). Thus, research has been carried out on the effects of music on the biology of different cell types. Study of effects of music on human chondrocytes has shown that use of music help to identify biomarkers and provide a new approach to the treatment of osteoarthritis (Vannoni 2012, Corallo et al. 2013, 2014, Dhungana et al, 2018, Exbrayat and Brun, 2019). On the other hand, it has been observed that the size and the granularity of tumoral MCF7 cells cultivated in vitro was altered by music (Lestard et al. 2013, Lestard and Capella 2016). In the lab Sprague-Dawley rats, music also decreased the enhancing effects of stress on the development of lung metastases provoked by previously injected carcinosarcoma cells (Nuñez et al. 2002).

Music has an effect on the deformability and aggregation of red blood cells and can therefore have an influence on some pathologies. In particular, effects on the surface properties of plasmic membrane have been observed. Membrane molecules such as adenylate kinase, show sensibility to the exposure to low frequency fields (Erken et al. 2008, Albanese et al. 2009). Acoustic vibrations affect fibroblast migration and cell morphology with formation of filopodia and lamellipodia (Mohammed et al. 2016).

#### *Specific Effects on the Immune System*

Several studies have shown the effects of music on the immune system of people under stress, or suffering from Alzheimer's disease, Parkinson's disease, or after a stroke (Hasegawa et al. 2001). The effects are visible on the activity of the natural killers (NK) cells and on the hormone norepinephrine level. Other researches have shown that rhythmic percussions can increase NKs cells and the amount of the hormone dehydroepiandrosterone relative to cortisol, indicating stress regulation (Lu et al. 2013). A variety of neuroendocrine ways also contribute to immune system changes (Bittman et al 2001, Hirokawa and Ohira 2003, Wachi et al, 2007).

Several experiments have also been carried out in rodents with pathologies and have shown a role for music on the immune system. In young and adult rats suffering from asthma, music modulates the number of leukocytes and the level of IL-4 (Lu et al. 2010). In lab BALB/c mice subjected either to noise or to music, thymus and spleen cell density, T cell population, splenocyte proliferation and NKs activity were enhanced by music (Nuñez et al. 2002). The survival of allografts in an experimental model of murine heart transplantation was significantly prolonged in animals exposed to occidental opera and classical music. Cell proliferation, IL-2 and interferon- $\gamma$  were suppressed in mice exposed to opera, while IL-4 and IL-10 were upregulated and CD4 +, CD25 +, Foxp3 + increased after exposure to certain types of music (Uchiyama et al. 2012a, b).



*Other Effects on Animal Organisms*

Several effects on animal behavior in different Vertebrates have been reviewed (Dhungana et al. 2018). Studies in chicken have shown that music reduces stress measured by various parameters (duration of tonic immobility, white blood cells/lymphocyte ratio and fluctuating asymmetry of the organism) (Bonzom 1999, Dávila et al. 2011). It is interesting to observe that the effects described according to the type of music and the animal species can be positive, negative or inexistent. In birds, it is known that the young learn the characteristic melodies of their species by listening to the adults. Young birds deprived of sound, either because they are deaf or because they are raised in isolation, away from the song of adults, are unable to sing. The learning of birdsong in relation to the intrinsic plasticity of neurons has been studied recently in zebra finch (Daou and Margoliash 2021).

Several results were also been obtained in monkeys: music can have effects in decreasing the heartrate of baboons, increasing the social behaviour in chimpanzees, or inducing an abnormal behaviour in rhesus macaques (Dhungana et al. 2018). In rats, music might improve spatial learning and memory ability (Xiong et al. 2018).

Effects of music have also been observed in domestic animals. In dogs, classical music can decrease vocalization and body shaking and increase sleep duration. Cats are sensitive to music and suitable musical pieces have been created (Dhungana et al. 2018). On the other hand, various effects have been observed in cattle. It has been observed that dairy breeds are more sensitive to sound, and especially music, than beef breeds (Dhungana et al. 2018). Increase or decrease in milk production depends on the noise levels. Loud noise or excessive sounds cause a stress of cattle and therefore a decrease in the amount of milk produced (Hemsworth 2003). In contrast, slow music can increase milk production contrarily to fast music (Algers et al. 1978, Algers and Jensen 1991). In buffalo, animal behaviour and reproduction are affected by music (Abuzead and Khalil 2007).

On the other hand, music seems to have effects on embryonic development, facilitating neurogenesis, and also regeneration and repair of neurons in Human (Kim et al. 2006, Fukui and Toyoshima 2008), and modulating expression of apoptosis in the development of auditory nuclei in chicks (Alladi et al. 2005). In a study devoted to the effects of music on the development, pairs of Wistar rats were exposed to classic music. Before parturition, the fetuses were extracted and brains prepared for electron microscopy. The results showed that prenatal music had an effect on neuroplasticity of fetal brain. As rat fetuses cannot hear until birth, these neuroplasticity changes of fetal brain could be related to a reduction in the mothers' blood corticosterone level (Sheikhi and Saboory 2015). In chicks, prenatal music stimulation leads to morphological changes in hippocampus and brainstem auditory nuclei. In contrast, unpatterned noise and loud music (110 dB) induce altered volume and neuronal number in these regions, indicating that the characteristic of the sound was mediating effects on brain development (Sanyal et al. 2013). Furthermore, it has been shown that *in ovo* sound stimulation (music or noise: 110 dB) affects the regulation of brain-derived neurotrophic factor (BDNF) in the developing auditory system of chicks; it was regulated at the transcriptional and

post-translational level in the auditory cortex and at the post-translational level in the hippocampus (Kathpalia et al. 2019).

According to some authors, music would also improve the success of fertilization rates of *in vitro* cultured human embryos (Lopez-Teijón et al. 2015).

At last, some studies have shown the effects of sounds and music on stem cells (Choi et al. 2016, Wei et al. 2016, Ventura et al. 2017).

#### *Some Adverse Effects on Animal Cells*

The effects of music cannot be equated with the effects of all types of sound. Research shows that not all types of sound have beneficial effects on the cells. There are sounds with harmful effects (Clark 1991). When the choroidal plexus of rats is submitted to noise, the number of normal cells decreased and the number of apoptotic cells increased (McCarthy et al. 1992, Aydin et al. 2011). In experiments conducted to analyze the effects of anxiolytics in rats, both noise and music suppressed the sexual behavior of females. In another experiment, noise suppressed the sexual impulses of ovariectomized females treated with high dose of estradiol and induced avoidance of the area where males were located (Le Moëne and Ågmo 2018a, b, Le Moëne et al. 2019). These studies show that in some cases, music can negatively affect animal behavior.

#### *Effects on Unicellular Organisms*

Like multicellular organisms, unicellular organisms, eukaryotes or prokaryotes, seem to be sensitive to music. Several works have shown the effects of single-frequency sound on the biology of various bacteria (Mortazavian 2012). Experiments using indian music have shown that it has a positive effect on the growth of bacteria and yeasts. Beneficial effects have thus been shown on cellular growth, metabolism and antibiotic sensitivity (Norris and Hyland 1997, Matsuhashi et al. 1998, Ayan et al. 2008, Shaobin et al. 2010, Sarvaiya and Kothari 2015, Shah et al. 2016). Growth, pigment production and antibiotic sensibility are affected by the intensity of sound in several bacteria (Kothari and Sarvaiya 2017, Khotari et al. 2018).

#### *Effects on Plants*

In plants, sound waves can influence germination, development and growth (Qin et al. 2003, Mishra et al. 2016, Vicient 2017). It can also enhance the immunity increasing tolerance to drought (Chivukula and Ramaswamy 2014, Choi et al. 2017, Lopez-Ribera and Vicient 2017). A recent study looked at the response of *Oenothera drummondii* plants to sound. The main result obtained is that the flowers of this plant produce a sweeter nectar only three minutes after being exposed to the rustling of the wings of butterflies and bees which are its pollinators (De Luca and Vallejo-Marin 2013, Veits et al. 2019). Other examples are consistent with the existence of an acoustic communication during interactions between plants and pollinators (Ayan et al. 2008, Mishra et al. 2016, Schöner et al. 2016).

More broadly, some animals and other plants can use the sounds emitted by a plant to obtain information about its condition (Khait et al. 2019).

Some studies have shown that the roots of various plants orient themselves towards the noise generated for example by flowing water (Gagliano et al. 2012, Gagliano 2013) and that the corn roots tend to grow towards a sound source whose frequency is close to 200 Hz (Gagliano 2013). Those different examples confirm that plants can also use sound, but the ecological and evolutionary implications that this represents in the life of a plant are not yet well known (Hongbo et al. 2008, Gagliano et al. 2012, Gagliano 2013). Further studies on plant bioacoustics are still needed to understand the interactions of plants with their environment.

### *Effects on Genome*

Studies have looked at the roles of various forms of genomic changes and gene regulation related to music abilities. Some genes inherited with musical aptitude have been identified. In particular, the alpha-synuclein gene, involved in song perception in songbirds, has been shown to be also overexpressed in individuals listening or performing music. Its mutation is associated to several cognitive diseases in humans and perturbations of song production and perception in songbirds. These observations are in accordance with an evolutionary conservation in biological processes related to sound perception (Kanduri et al. 2015, Järvellä 2018). On the other hand, changes in the peripheral blood microRNA transcriptome after 2 hours of concert performance are identified in professional musicians, suggesting regulatory mechanisms underlying auditory perception. Based on the current knowledge about the microRNA function in blood and brain, the authors interpreted the regulation of these non-coding RNAs as consequence of a regular musical activity. In brain, the putative targets of these microRNAs were involved in neuronal activity, neuronal plasticity, myelination and cognitive functions (Nair et al. 2019, Nair et al. 2021).

It has been shown that Indian Vedic music can upregulate the expression of steroidogenic genes in 3D cultured buffalo granulosa cell spheroids (Pandey et al. 2021).

Proliferation of gastric cancer cells did not increase when cells were exposed to classical music contrarily to those exposed to metal music. The expression of several genes involved in proliferation seems to be modulated in different ways according to the music type (Ramírez-Rivera and Bernal 2019).

In order to give a molecular basis to effects of music on organisms, a metaanalysis of 105 publications concerning humans and several animal models identified several candidate genes related to musical traits. The authors have shown that these genes are involved in biological functions underlying learning and memory, which are essential properties for music abilities (Oikkonen et al. 2016). A study of properties of audible sound as mechanical stimulus by cells has shown an effect of wave form and sound pressure level, more than frequency, on gene expression, with a cell type-specific response to sound (Kumeta et al. 2018).

### **Reception of Vibrations and Intracellular Repercussions**

How vibrations can intervene on cellular physiology? The effects of vibrations are well known in hearing cells. These cells also called “hair cells” are sensory cells emitting cilia which are really cytoplasmic expansions, the stereocilia. These cells are arranged along the basilar membrane of the cochlea (still called “organ of Corti”). Depending on their position on the cochlea, cell membranes are sensitive to vibrations at well-defined frequencies. The vibrations cause a deformation of the membrane of these cells at the level of the cilia which amplifies the surface of reception of the vibrations. The deviation of the stereocilia causes the opening of ion channels creating an electrical receptor potential.  $\text{Ca}^{++}$  ions enter the cell, releasing glutamate, a neurotransmitter at the level of the synapses in connection with axons of neurons. The signal is transmitted to the auditory areas of the brain. This type of interactions between cell membrane and vibrations can certainly be generalized to all cells.

All cell membranes are made up of a bilayer of phospholipids in which proteins are incorporated. This membrane is bound outside the cell and can carry receptors; it is also linked directly to the cytoskeleton and to the enzyme systems located inside the cell. Even if studies specifically related to the mechanism of the effects of the sounds received by cell membranes are still lacking, the analysis of works on membrane receptors, the nature of the signals and the elastic capacities of the cell allow us to make assumptions as to these mechanisms.

At the cellular level, it is certainly in plants that work is the most advanced. Sound vibrations can affect microfilament rearrangements, increase the levels of polyamines and soluble sugars, alter the activity of various proteins, and regulate the transcription of some genes (Qin et al. 2003, Hongbo et al. 2008, Mishra et al. 2016). The reception of chemical signals by animal cells is well known. Various stimuli such as light, ions, pheromones, hormones or neurotransmitters, bind to G protein-coupled receptors located on cell membranes. Then, they transduce these extracellular signals inside the cells by engaging G proteins, that trigger a cascade of signaling events leading to an appropriate cellular response (Lim et al. 2015, Syrovatkina et al. 2016). Further studies on the modalities of acoustic signal capture will provide a better understanding of the intracellular repercussions of sound. Elasticity of biological tissues can be measured by elastography. This imaging method makes it possible to understand the variations in the hardness of tissues and their elasticity (Brum 2012, Grasland-Mongrain 2013) as a consequence of the links that membrane receptors establish with the elements of the cytoskeleton (Icard-Arcizet 2007).

Reading these works, we can assume that sound vibrations trigger the plasmatic membrane’s vibration, which could result in the activation of certain proteins of the G protein type and the transmission of a chemical signal in the cell. Several metabolic reactions governing the physiology of the cell could then be affected.

A controversial theory, the “proteody theory”, emitted by the French particle physicist Joël Sternheimer at the beginning of the 1990s, defended the idea of the existence of waves emitted in the body molecules. Unfortunately, no scientific

publications are available for now (Doux 2019). According to this theory, waves whose frequencies can be transcribed into musical notes are associated with each group of amino acids. In the same vein, King and Angus (1996) published a computer program called PM (protein music) to analyze information about protein sequences by audification, i.e. using the hearing to analyze data (Kramer 1994).

Petrovski et al. (2021) found a correlation between yeast vacuolar proton-ATPase activity (involved in many life processes) and the intensity of several frequencies of an oscillating electric field generated by music. These observations led these authors to conclude that such an electric field from the music interfered with the periodic transmembrane movements of the enzyme. Based on the fact that organisms are subject in nature to several rhythmic oscillations, Muehsam and Ventura (2014) give a theoretical study in which they examine the effects of sound vibrations on gene expression.

## Conclusions

During biological evolution, organisms have acquired senses that allow them to interact with the environment. The sensory perception of living organisms is very diversified and is directly related to the lifestyle of the organism. Several of those senses will be put to good use by art in Human. Among the arts, music is directly related to the sensory system of hearing. While the effects of sound vibrations on auditory cells have long been known, the effects on other cell types are much less well understood. Currently, an increasing number of works is investigating the effects of music on the biochemistry of non-auditory cells and on various aspects of metabolism. Nevertheless, these works remain still quite disparate.

Music elicits reactions in humans that promote positive emotions, stress relief and immune function, by soliciting different cellular signaling molecules including hormones, neurotransmitters, cytokines, and peptides (Gangrade 2012). Music can restore some of the homeostasis and thus reduce pain (Nelson et al. 2008). It probably reduces alterations in the hypothalamic-pituitary hormonal axes (Russo et al. 2017). Music (432 Hz) can also influence growth, by increasing food intake and body weight; a significant increase of ghrelin expression was found in hypothalamic neurons in music-treated rat pups (Russo et al. 2021). A hypothesis involves quantum mechanics. But beware of the enthusiasm aroused by these exciting results. Studies are still necessary to understand and go further in the possible applications, the precise molecular mechanisms of its effects indeed yet to be clarified. But there is a field of research emerging here.

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## Motivation and Development – Using Poly-Universe Game in Teaching Mathematics and Other School Subjects

By Ilona Téglási\*

“Children learn as they play. Most importantly in play children learn how to learn.” (O. Fred Donaldson)

*Motivation and development of different skills are keywords in teaching mathematics all over the world – and how can we achieve these better than by playing? János Saxon-Szász, a Hungarian artist invented the Poly-Universe game. It is a game of arts and mathematics. In our presentation and paper we would like to introduce the artistic and methodological background of using the game in teaching different fields of mathematics on different ISCED levels. As well, in an international consortium (Poly-Universe in Teacher Training Education, Erasmus+ Strategic Partnership, 2020-1-HU01-KA203-078810) we have a research project on how to implement these methods into teacher training education through using the Poly-Universe game. After the first semester of pilot courses in our partner institutions we would like to present the experiences and outcomes of them – and to raise your interest in further development.*

**Keywords:** *game-based learning, teacher training, arts and mathematics, motivation*

### Introduction

Learning mathematics is hard work for most of the pupils in the world. Though they accept that mathematics is important for life, the majority of them do not like it. So a good teacher of mathematics has to catch every opportunity to make it more enjoyable and easier to learn. We have already learned from Dienes (1960) in the late 1960's and 1970's, that through games, many mathematical structures can be taught. Nowadays his ideas are getting more popular again. The world is changing so quickly that we have to realise that the development of skills and abilities are more important than the content of teaching. So we have started to think in competence based teaching strategies. The information nowadays is available for more and more people through the internet, so in the classroom not the teacher is the only source of knowledge. We use less frontal teaching methods and more cooperative teamwork in the classroom – thanks to Dewey (1960), Johnson and Johnson (1975), Cohen and Lotan (1997), and others. The educational approaches are changing consequently as we know more and more about the brain, memory, development of childrens' mental skills and personality. Anyhow, there are a lot of possibilities to make the learning of mathematics easier and more motivation for pupils – which can be equally good and effective. The aim of the

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present paper is to introduce a special tool for this purpose: the Poly-Universe game set, and the research project for introducing it into teacher training education.

### The Game as an Educational Tool

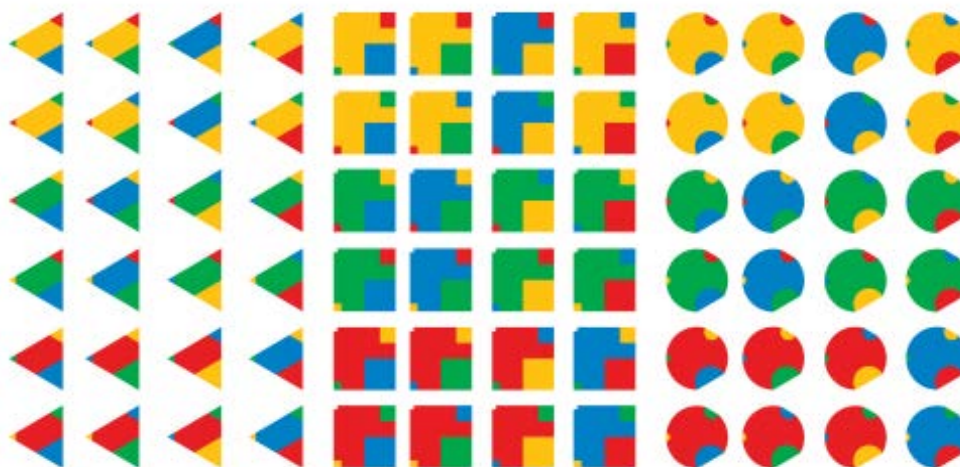
The Poly-Universe game was invented by a Hungarian fine artist, János Saxon-Szász (<http://www.saxon-szasz.hu/>). He is an internationally known representative of the MADI artistic movement. In his constructivist geometric art there is an important role of rates, self-similar shapes, affine transformations. He calls these kinds of structures “poly-dimensional” (Darvas 2020). From this artistic background came the idea of the Poly-Universe game set, which was invented originally for creative artistic use. But it soon became clear that this game has got many connections to mathematics. The pure shapes, clear colours and the system of combinatorial varies makes it a perfect tool for using them in teaching mathematics (Figure 1).

**Figure 1.** *The Three Shapes of the Poly-Universe Game Sets*



The novelty of the game comes from the scale shift symmetry of the three basic shapes (triangle, square, circle) and the colour combination system (red, blue, green and yellow). In one set we can find all variations of the colours on the parts of one element. The rate of the parts on every shape is 1:2:4:8. So it is easy to count that the different elements have got 24 variations each shape – that’s what the game sets consist of (Figure 2).



**Figure 2.** *The Elements of the Three Poly-Universe Game Sets*

This simple system of attributes and the aesthetic design makes this game useful for teaching different fields of mathematics from geometry to combinatorics and probability theory. Besides this it is a game of art and creativity, so it can also be used as a motivation or a special viewpoint for complex mathematics lessons, planned with STEAM methods. See more about the game: <http://www.poly-universe.com/>.

Based upon several experiences at conferences and school workshops, between 2017-2019 the Poly-Universe Ltd. company in consortium with partner schools from Hungary, Finland, Slovakia and Spain realised an ERASMUS + project to develop a new visual approach for mathematics education based on Poly-Universe games. Within the project the partner schools tried out in different educational levels and fields of mathematics (from elementary school to upper secondary level and mathematical talent care) how the games can be used for motivating the students, for developing their mathematical competences. During the 18 months of the project the partners (teachers and students together) discovered many applications for using the game in teaching mathematics and arts in an experience-centred visual way. The main objective of the project was to work out a new visual mathematics educational system, the PUSE Methodology.

The result of this project is a collection of tasks from elementary school education (ISCED1) to secondary school education (ISCED3) in the following fields of mathematics education:

- Geometry and measurement.
- Combinatorics and Probability calculations.
- Sets and Logic.
- Graphs and Algorithms.
- Complex and Visual tasks.

The PUSE Methodology book is an impressive publication beginning with the description of the game, the background of the game and more than 300 tasks

(worksheets for students and teachers) (<http://www.poly-universe.com/puse-methodology/>) (Saxon et al. 2019). On the dissemination events of the PUSE project the participants spread these methods and practises and made available EU-wide in school education. The webpage of the project still exists, so that every teacher interested in this game, method and approach can find and adapt it to his/her own teaching practice.

### **Poly-Universe in Teacher Training Education (PUNTE)**

After finishing the PUSE project, a demand arose in the coordinators to continue and extend the development they'd started. It has been seen from the start, that there are so many possibilities in the Poly-Universe game that the PUSE Methodology is not a closed system. There were many unsolved problems, and more tasks that could not belong to any of the chapters of the book. So we've tried to find the best continuation of the work done before. For that, we have been looking for partners in the field of teacher training high school education who are interested in using new innovative methods. We think that the best way to reach changes in the teaching practice in schools is to start changing the methods in teacher training education. If we show new possibilities and approaches for future teachers, it might be a fruitful start to reach our target: make school practise more playful, joyful and experience centred, while a real development of skills and abilities realises in pupils.

So for continuing the work we have applied for an Erasmus+ support for our plans with the following partnership:

- Eszterházy Károly Catholic University, Eger, Hungary (consortium leader)
- Partium Christian University, Oradea, Romania
- University of Coimbra, Portugal,
- University J. Selye, Komarno, Slovakia
- Poly-Universe Ltd., Budapest, Hungary
- Johannes Kepler University, Linz, Austria
- Experience Workshop Ltd., Jyväskylä, Finland
- Technical College of Applied Sciences, Subotica, Serbia (Figure 3)

**Figure 3.** Partnership of the PUNTE Project



Finally we have succeeded in winning the grant, and started working in the “2020-1-HU01-KA203-078810 Poly-Universe in Teacher Training Education (Erasmus +, Strategic partnership)” (PUNTE) project in autumn 2020.

The ultimate aim of PUNTE project is to develop, test and disseminate new innovative pedagogical methods, build a new educational framework for improving transversal skills and stimulate a kind of visual paradigm shift in teacher training

higher education in various fields of teacher training programs in the partner institutes.

The main technical and methodological tools of this educational framework are based on the revolutionary educational tool, the Poly-Universe game. In the last 10 years, this game was tested by thousands of teachers and students belonging to different age groups (6-18) in hundreds of institutions and events (school workshops, conferences, art & mathematics festivals, museums) throughout Europe. As we've mentioned before, our project is also based on the highly successful predecessor project PUSE (Poly-Universe in School Education), where this game was introduced to various forms of school mathematics education. The PUSE project, although it was very successful in quantitative and qualitative terms as well, was evidently not able to enforce systemic change and did not reach the level of higher education. The aim of the PUNTE consortium is to make some significant steps further. Our objectives are as follows:

- Collect best practices of applying Poly-Universe in various fields of school practise (different subjects, formal and informal pedagogical situations).
- Create and test a theoretical and practical methodological framework of improving transversal skills by Poly-Universe.
- Introduce this pedagogical framework to regular teacher training higher education and stimulate methodical paradigm shift through this method;
- Develop, adjust and publish open source teacher training materials supporting various forms and paths of teacher training higher education (distant learning, modular forms, blended learning etc.).
- Disseminate the results in the European Higher Education Area and involve policy makers to further support long-term systemic change in this field.

Although the most obvious field of application of Poly-Universe is in arts and mathematics education, we definitely follow a deeply interdisciplinary approach – we strive to find and develop pedagogical aspects through which this tool can also be applied in several other fields, including the entire spectrum of STEAM and beyond: Physics, Geography, Computer Science, Economy, but also in Communication and Literature.

Since Poly-Universe has proved successful in the development of a large variety of age groups, our methodological approach is planned to be as comprehensive and inclusive as possible. The educational portfolio and methodical research of the applicant institution (Eszterhazy Karoly Catholic University) and members of the consortium actually cover the entire spectrum of teacher education, from preschool teachers to upper secondary level. The project also intends to develop cross-cutting key competences of future teachers at all levels, which, in the long term, can support the development of these competences at every level of the education.

Moreover, the consortium pays special attention to inclusiveness. Techniques and methods to support educators in teaching students with special needs and

pupils with various social backgrounds are also in the forefront of our cooperation. These methods can further support societal inclusiveness in education.

Some of the planned activities:

- Desk research:
  - collection of best practices;
  - joint development of methodological and pedagogical tools.
- Test and improvement, including mobility activities:
  - short- and long-term mobility of educators to introduce and test various aspects of the developed teacher training methods;
  - organisation of joint project meetings and training where educators can further be trained.
- Dissemination and communication activities:
  - in-house and out of consortium multiplier activities (presentations and workshops in other higher education institutions and schools, meetings with policy makers etc.);
  - communication of the results to the wider audience (info-days, Researcher's Nights, local and international conferences, publications etc.).

To reach our targets the following intellectual outcomes are being developed:

- IO1: PUNTE Methodological Study – Handbook for pre-service and in-service teachers and students.
- IO2: Framework and curricula of PUNTE methodological courses for pre-service teachers, students of teacher training education.
- IO3: Task repository for collecting new applications of using Poly-Universe in a wide spectrum of school subjects, for formal and informal teaching/learning situations, for inclusive education also.

## **Intellectual Outcomes of the Project**

### *Methodological Study*

This study is meant to be the base of our PUNTE methodical courses. For this purpose, we have summarised the theoretical, methodological, artistic background of using the Poly-Universe in teaching for different specialisations of teacher training education: preschool teachers, elementary teachers, teachers of special needs children, teachers of lower and upper secondary levels (mathematics and other subjects). The authors of the study are experts from our partner institutes,

researchers and educators from various fields of teacher training education: psychology, pedagogy, subject methodology, computer sciences, fine arts, mathematics.

In the first part of the study we present those teaching-learning theories, which are behind the method:

- Constructivism in pedagogy.
- Problem solving in Mathematics teaching, Bruner's learning and representation theory.
- The Dienes-Varga method.
- Inquiry-based strategies in mathematics education.
- Philosophy of STEAM education.
- The role of games in learning.
- Visuo-spatial skills and their development.
- Motivation and engagement on learning.
- Inclusion in education.

Most of these themes are parts of the students' regular training system. We selected especially those theories that have got the most connection to our goal: introducing the Poly-Universe game into their teaching practice.

The second chapter is about learning-teaching through art, because we think that it is crucial to understand the mentality behind the game (Saxon and Dárdai 2019). So we can learn from the following topics in this chapter:

- "Teaching to see" – a dimension change in geometric art and education.
- Fundamentals of geometric art in the 20th century and its correlations to pedagogy.
- Art Concrete and the MADI movement.
- "Let it play" – the role of geometry in education.
- Dimension Pencil – an imaginary tool for changing pedagogical approach by János Saxon-Szász.
- About the Poly-Universe elements: triangle, square and circle – and the philosophy of the game.
- Friezes, rosettes and Poly-Universe - symmetry groups in different patterns from rosettes to the traditional Portuguese tiles.

The third part of the study is about the methodological background – to present the most important teaching-learning strategies for the realisation of the application of the Poly-Universe game (Nagy and Révész 2019). This part is more practical, with concrete proposals:

- Cooperative learning and its benefits.
- Playful learning and guided play.
- Gardner's multiple intelligence theory combined with Bloom's taxonomy: the activity matrix.
- Creativity in general and in mathematics education.

- Holistic approaches and creative learning in the Finnish education system.

At this point we have reached the second main aim of the PUNTE project: working out the framework of university courses based on these theories and strategies. So the next chapter deals with the place and tools of Poly-Universe in teacher training:

- About Poly-Universe in formal and informal learning contexts.
- The fields of using Poly-Universe in teacher training education.
- The framework of PUNTE methodological courses – a proposal.
- Dynamic GeoGebra applications inspired by Poly-Universe – involving online tools.
- Poly-Universe digital game interface – developing a new e-learning platform.

At the end of our study we show about forty concrete tasks for using Poly-Universe in the following subjects:

- Mathematics (beyond the previous PUSE Methodology book).
- Arts.
- Interdisciplinary approaches.
- Inclusion.

These tasks are not just for illustrating the wide spectrum of the usage of the game, but also for the purpose of giving hints for the students, to start thinking about new applications and awaken their creativity.

It would not be fair, if I did not mention the co-editors and the co-authors of this book, so let me list them: Branko Anđić (JKU), Bettina Bakos (JKU), Maria de Graça Bidarra (UC), Anikó Bordás (EKCU), Andrea Bordás (PCU), Zsuzsa Dárdai (PU), Edith Debrenti (PCU), Zoltán Fehér (JSU), Kristóf Fenyvesi (EW), Miklós Hoffmann (EKCU), Ladislav Jaruska (JSU), Zoltán Kovács (EKCU), Zsolt Lavicza (JKU), Zoltán Papp (VTS), Vanda Santos (UA, on behalf of UC), Gordana Stankov (VTS), János Szász Saxon (PU), Eleonora Stettner (PU), Eva Ubrich (JKU), Maria da Piedade Vaz Rebelo (UC), Ilona Téglási (EKCU).

And special thanks to János Szász Saxon for the fantastic layout, and to the Líceum Publisher of the Eszterházy Károly Catholic University for taking care of the publication procedure (Figure 4). The whole study can be downloaded from the project webpage: <http://www.punte.eu/punte-study/>.

**Figure 4.** The Front Page of the PUNTE Study

### *PUNTE Courses*

The main aim of the courses is to reveal how the Poly-Universe game can be used in an experience-based, enabling differentiated development teaching methods, for students of different levels of teacher training education (from special education to subject teachers). The course aims to construct a teaching-learning environment through which the students can realise that the Poly-Universe game is an appropriate tool for raising motivation, developing creativity and involve pupils with learning difficulties in teaching different subjects. As the specialties of the students are different in the different partner institutes, when planning the content of the PUNTE courses we were cogitating a modular structure, to be able to choose among the modules and adapt them to the requirements of the users (Table 1).

**Table 1.** Modules of the PUNTE Courses and Their Types

Modules	Module's type
1. Introduction	compulsory
2. Geometry and the methodology of its teaching	compulsory
3. Combinatorics and the methodology of its teaching	optional
4. Informatics and the methodology of its teaching	optional
5. Developing logical thinking	optional
6. Complex, interdisciplinary problems	compulsory
7. Poly-Universe as concrete representations in solving problems	compulsory
8. Electronic version of Poly-Universe	optional
9. Games in teaching with Poly-Universe	compulsory
10. Helping disabled students' in learning and communication with Poly-Universe	optional
11. Poly-Universe and art	compulsory
12. Presentations of students work	compulsory

During the completion of the course we expect the following competences of the students to be developed:

a) Knowledge

The students should get acquainted with the Poly-Universe toolkit and its artistic background. The students should learn about the pedagogical-psychological theories which give the base for using the game in teaching situations. The students should acquire those methodological tools and approaches with which they will be able to plan a teaching-learning unit using the Poly-Universe game.

b) Skills and abilities

The students evolve in abstract, logical thinking, analytical skills, spatial seeing, problem solving, problem posing and model-making abilities through practising with the Poly-Universe game on the course. The students' creativity can also evolve by planning new exercises and games.

c) Attitude

Fulfilling the expectations of the course should raise the empathy and tolerance of the students when teaching pupils with learning difficulties or special needs, regarding differentiated development strategies. The students should be engaged in teaching his/her own subject using experiential teaching methods. The students should be sensible for involving visual arts in teaching/learning procedures.

d) Autonomy and responsibility

After the course the students should be able to work out a special topic (regarding his/her specification) of planning a lesson using the Poly-universe game independently. The students should be able to reflect on a task or a lesson plan where the Poly-Universe game was used: effectiveness, conformance to the awareness of the curriculum, appropriateness, meeting with children's needs, realisation differentiated development of children (Publications Office of the European Union 2002).

At the Eszterházy Károly Catholic University we have worked out and run the course with the following content and schedule at the 2nd semester of the 2021/2022 academic year:

1. Introduction – Getting acquainted with the elements of the Poly-Universe game family, discussing the characteristics and the artistic background of it. Theoretical background of usage in teaching-learning procedures (self-study by e-learning materials). (2 lessons)
2. Poly-Universe and arts. Teaching-learning through arts. (2 lessons)
3. Using Poly-Universe in teaching geometry – methods, exercises, ideas. About spatial skills and their development. Using Poly-Universe in the development of combinativity – problems from the field of Combinatory. (2 lessons)



4. Development of abstract, logical thinking and analytical skills with the Poly-Universe game. Complex and interdisciplinary problems, where Poly-Universe can help model the solution. The theory of Problem Based Learning methods. Using Poly-Universe as a concrete/material representation form in problem solving – the role of different representation forms in learning procedure. (2 lessons)
5. Poly-Universe in a digital environment – using GeoGebra for solving problems connected to the game. The methodology of using ICT tools and material tools during the teaching/learning procedure. (2 lessons)
6. The role of games in teaching-learning in general. Presenting game-based teaching methods through Poly-Universe games. How can the Usage of the Poly-Universe games help in the development of pupils with special needs, special attention or learning difficulties? (2 lessons)
7. Presenting the students' projects – worked out individually, in pairs or small groups, where the use of Poly-Universe appears in a certain learning activity – and evaluation. (2 lessons)

The course was held with attendance of the students and aided by e-learning material. For the e-learning platform we have used the Moodle system of the Eszterházy Károly Catholic University (<https://elearning.uni-eszterhazy.hu/login/index.php>). We've used this platform to disseminate the theoretical knowledge of the course, and for an online communication between the educators and the students, and also to upload the students' works and projects, and finally the evaluation of the course. The participants of the course were students of the following specialisations: teacher of special needs children, elementary school teacher, secondary school teacher of mathematics, arts, geography, informatics, physics, chemistry, physical education (in different pairs of subjects). On some multiplier events the description of the course had taken the attention of some in-practice teachers of mathematics, so we have also announced a short, intensive course for part-time students of teachers of mathematics.

During the lessons we have used the Poly-Universe game family, paper, pen, notebook, scissors, glue to process the theoretical background and to construct new tasks and games. The students have worked in groups of 3-5 members on all lessons, and we took special attention on forming heterogeneous groups of them (regarding their specialities and interests). We have also used cameras and smartphones to take photos and short videos about the students' activities.

The requirements of the course for the students were:

- Active participation in the lessons and in the project work.
- Presentation of 1 chosen theoretical issue on one of the lessons.
- Working out a project and presenting it individually, in pairs or in small groups at the last lessons.

The students had to choose a special topic to work out till the end of the course in pairs, small groups or individually. The evaluation of the acquired knowledge and competences took place through a presentation of their project

work, according to given viewpoints (applicability, feasibility, meeting the expectations of the curricula and methodological studies). These final presentations and the description of the students' projects have been uploaded to the e-learning platform of the course.

For the evaluation and quality assurance of the PUNTE project during the semester we've observed some lessons (at the beginning, in the middle and at the end) according to the following guidance:

- Information about the lesson/session (date, place, duration, number of participants, topic of the activity).
- Description of the activities through detailed answering of some questions (How did the activity begin? What did the teacher do? How did students get involved? What was the task proposed? How was it developed? What were the materials used? How were they used? Did the students reproduce models or did they create new ones?)
- Analysis of the reproduction process: How was the reproduction developed? Which were the strategies used? Did the students start with all materials or do they choose piece by piece? Was it an intuitive copy? In case that a new model is produced, analysis of the new model.
- Analysis of the students' behaviour: How did the students continue work? Did they collaborate? Did they share materials while developing their own product or did they develop the task together? Did students ask questions?
- Reflection on the session: positive and negative aspects, difficulties, engagement, development, successfulness, effectiveness, suggestions for improvement.

To evaluate the pilot courses in the partner institutes we have used a post questionnaire after each course. The main part of it was an Intrinsic Motivation Inventory Questionnaire (<https://selfdeterminationtheory.org/intrinsic-motivation-inventory/>) (Plant and Ryan 1985). We have used the following subscales of the original test, and modified slightly the items to fit the specific activity, the university PUNTE courses:

- Interest/ Enjoyment
- Perceived competence
- Effort/Importance
- Pressure/Tension
- Perceived choice/autonomy
- Value/Usefulness

Beyond the intrinsic motivation we have added some more statements referring to the specific course to be able to improve them:

- It was easy to start using Poly-Universe.
- It will be easy to use the Pol- Universe in mathematics.

- The Poly-Universe can be used in different scientific areas.
- The Poly-Universe can be used in different educational contexts, e.g., formal, non-formal, informal.
- Poly Universe can be used to implement games in education.
- With Poly Universe, I know how to plan and implement interdisciplinary activities.
- I think that in the future I will be able to do activities similar to the ones done in the PUNTE module.

For the scoring of the questionnaire we have used the Likert-scale from 1 to 5 (1 – the statement is not at all true for me, 5 – the statement is fully true for me), attending to the scores of the reverse statements too.

As in the main aims of the PUNTE project we have put special attention on the development of transversal skills, in the post questionnaire we've asked the students to point out, which of the following can be developed in the children through playing/learning activities with Poly-Universe by their opinion:

- group work
- creativity/creative thinking
- critical thinking
- understanding
- problem solving
- sharing/cooperation
- concentration/attention
- innovative thinking
- decision-making
- autonomy
- responsibility.

In addition, for the improvement of the pilot courses we have asked four questions to give a chance to the participants to explain their ideas about the Poly-Universe course by answering with a few sentences:

- What did you enjoy most during the course activities?
- What were the difficulties for you?
- What have you gained most from the course and why is it useful for you?
- What are your suggestions for improvement of the course?

The analysis of the answers for the whole questionnaire is just in front of the partnership, and planned to be published in the near future. As the courses will follow up in the partner institutes also in the next academic year, it is essential for us to draw the inferences from the pilot year, and improve the content, the learning environment and other circumstances as we can.

*Task Repository*

The third main intellectual outcome of the PUNTE project is meant to be a Task Repository for the application of the Poly-Universe game in various learning/teaching situations. The planned fields of the applications are:

- Mathematics
- Programming and algorithms
- Arts
- Inclusive learning
- Interdisciplinary approaches
- Language skills and communication
- Sciences
- Logic games

As well as in the previous PUSE project, in PUNTE there are several occasions for workshops with the Poly-Universe game (multiplier events, short intensive courses, project meeting days, conference workshops, etc.) we have many possibilities to collect the newly invented tasks and problems to be solved. Also the sessions of the PUNTE courses give the opportunity to create new approaches in the different modules and in the students' own projects. To collect these tasks we have created a template for describing a task or an activity with Poly-Universe. On this template there are some general information about the author, the recommended level of using it (ISCED1 to 5), the purpose of the task/activity (formal or informal learning/teaching, inclusive teaching, free time activity, etc.), school subjects (if relevant), the expected benefits of solving the task or doing the activity (UNESCO 1997). Of course, the largest part of the template is the detailed description of the task/activity with figures or photos included, and additional comments of the author for the future user.

The main aim of this Task Repository is to show and disseminate the wide spectrum of applications of the Poly-Universe game both in fields and levels. For disseminating these tasks, we have developed our own webpage for the PUNTE project: <http://www.punte.eu/>.

The collecting, analysing and evaluating of the tasks is still in progress, and that will be the third intellectual outcome of the PUNTE project. Having had many occasions to work with the game, we know that every time some new ideas and problems occur. Sometimes, we find the solution soon, but sometimes it takes a longer period to put an end to a special problem. We know that this Task Repository will never be finished. Besides the original aim, that is to collect the best practices, it is also to create a place where the new users can upload their new ideas – after a quality control by the experts of the area of the task/activity.

## Conclusion

The aim of the present paper was to introduce and describe a progressive initiation of widening the methodological preparedness of students in teacher training education Europe-wide through a revolutionary game called Poly-Universe. Our main target is to show how modern approaches of teaching/learning strategies can be involved in teacher training education, giving the theoretical base as well as an active, practical experiment to the students aided by an online learning platform.

As detailed above, the developments of the project (the intellectual outcomes) are partly finished, but some are in progress. The first result of the project is the PUNTE methodological study, which can be downloaded from the project webpage: <http://www.punte.eu/punte-study/>. The second outcome taking shape in university courses at the partner institutes has just come to end. During the summer of 2022 the first pilot courses will be evaluated and improved, modified if needed for the next academic year. The first impressions of the courses made by the educators are the following:

- The students were keen on taking part of the course.
- They liked working in groups, and discovering the different possibilities of the game. They have worked out chosen theoretical parts of the small groups also, with given literature and presented it to the other students. This kind of learning experience was also new and interesting for them, as they mentioned at the ending evaluation (“It was good that we have learned from each other, and not from the teachers.”).
- The teaching-learning environment of the courses were also an example for their future practice.
- Most of the participating students were very creative and innovative in finding out new applications with the Poly-Universe game. These applications will be ridged of the Task Repository of our project.

The third result of our project will be a Task Repository of special applications for using Poly-Universe in different pedagogical situations. This phase is still in progress.

So we cannot show a final result yet. But with this paper, we would like to raise the readers’ interest in this unique game, the Poly-Universe. This game is universal for developing childrens’ skills and abilities (problem solving, creativity, spatial seeing, algorithmic thinking, inductive and deductive thinking, analysing – just to mention a few). Also a wonderful tool to raise and keep pupils’ motivation for learning and their competence motivation. The target group of the project is university students of teacher training education – any specialisation – but our team is open to multiplying the methods to other areas of higher education also. So if the paper and the web pages raise your interest, don’t hesitate to contact us in the hope of future cooperation or dissemination.

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**Bio-rationale Management of Tomato Leaf Miner,  
*Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae)  
Using Extracts of Neem (*Azadirachta indica* A. Juss)  
Jimsonweed (*Datura stramonium* L) and Periwinkle  
(*Vinca rosea* L.)**

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Recently, tomato leaf miner (TLM) *Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae), is the most notorious pest of tomato worldwide causing severe reduction of yields in both protected and open fields. In Sudan, the pest was recorded to attack all tomato cultivation areas causing considerable damage affecting income of poor farmers. Various pesticides of different active ingredients are applied excessively and routinely to control *T. absoluta* in tomato. As known, reliance on insecticide cause adverse impacts in human health, create insect resistance as well as affect environment and natural enemies. This study is initiated to evaluate the efficacy of extracts of 3 botanicals as alternative to synthetic insecticides against *T. absoluta*. A randomized Complete Block Design field experiment was conducted at Takroof experimental farm of Kassala and Gash Research Station, Sudan during season (2019/2020). The experiment consisted of Neem seed oil, water extracts of *Datura*, Water extract of *Vinca*, Dancid®; synthetic insecticide as standard, and non-treated treatment as control. Each treatment was replicated thrice Data included number of infested plants/plot, number of mines/plot, percentage of infested fruits and yield (Ton/ha) were compiled, variance among treatments (ANOVA) was statistically analyzed and means were separated using Duncan Multiple Range Test (DMRT) applying SAS 9 a computer based program. The results of this study, revealed high significant difference between treatments in the number of infested plants/plot, number of active mines/plots for the three assessment times of the post spray counts. Water extract of *Datura* and Neem seed oil were better than Dancid® and *Vinca* in reducing the number of infested plants/plots and number of active mines/plots. All test products were significantly same in reduction the percentage of infestation of fruits and they were less than the control. Also high significant difference was observed between treatments on yield. Plots treated with Neem seed oil obtained the highest yield followed by WE of *Datura*, Dancid®, WE of *Vinca* with 11.2, 9.9, 9.7, 8.8 (Tons/ha) while the un-treated plots obtained the lowest yield (3.8 Tons/ha). For their potency, cheapness, easy processing and environmental friendly characters, Neem seed oil, WE of *Datura*, and WE of *Vinca* are recommended to be used to control *T. absoluta* in tomato crop.

**Keywords:** *Tuta absoluta* neem seed oil, *Datura*, periwinkle, aqueous extracts

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## Introduction

Tomato (*Lycopersicon esculentum*, mill) is one of the most leading vegetable crops worldwide. Tomato ranks second to onion among the most important vegetable grown in Sudan. The main production areas of tomato in Sudan are Gezira Khartoum, Kassala and Northern States (Elassi 2001). Tomato crop has been reported to be attacked by various serious insect pests and disease, that have the potential to drastically reduce its yield such as yellow leaf curl virus disease which is transmitted by whitefly, *Bemisia tabaci*. Leaf miners, *Liriomyza spp*, the African boll worm (ABW) *Helcoverpa armigera* are among the most important insect pests of tomato since long time. Worldwide tomato crop witnessed a highly voracious invasive pest; Tomato fruit borer (*Tuta absoluta*), that can completely rescind the crop. Tomato is the main host plant of *T. absoluta* but the pest also attacks other crop plants belonging to the nightshade family, including potato, eggplant pepper and tobacco. It is known from many solanaceous weeds, including *Datura stramonium* *Lycium chilense* and *Solanum nigrum* (Biondi et al. 2018, Desneux 2010, Mohammed et al. 2015, Mansour et al. 2018). Tomato fruit borer is originated to South America and due to the importation of tomato to Europe. It invaded Europe, Middle East, North Africa and spread all offer the African content within very short period. In Sudan *T. absoluta* was officially recorded as injurious pest of tomato in 2011 but its impact on tomato is very devastating when compared to other insect pests. The feeding of larvae causes significant damage on leaves, stems, buds and fruits leading to yield losses up to 100% if the pest is not controlled (Desneux et al. 2010). Recently, this pest is one of the main reasons that decline tomato yield in Sudan. Outbreak of Tomato fruit borer was observed in many states Sudan causing a damage up to 80% (Mohammed and Khalid 2011). Management of insect pests is crucial to ensure good crop productivity. Experiments have revealed some promising agents of biological pest control for this moth, including *Nabis pseudoferus*, a species of damsel bug, *Bacillus thuringiensis* and *Beauveria bassiana* (Molla et al. 2011, Guedes et al. 2019). The entomo-pathogenic nematodes *Steinernema feltiae*, *Steinernema carpocapsae*, and *Heterorhabditis bacteriophora* were found very effective for the control of *T. absoluta* (Husin and Port 2021). Buragohain et al. (2021) reported that the use of commercial formulations of *Bacillus thuringiensis* reduced the infestation of leaves and fruits by *T. absoluta*. The sex pheromone of *T. absoluta* has been found to be highly attractive to male moths (Mohammed et al. 2013, Mahmoud et al. 2020). Application of insecticides is the main method used to control *T. absoluta* in Asia and sub-Saharan Africa, including Sudan, due to absence of other management techniques. As reported by (Lietti et al. 2005) resistance of *T. absoluta* to insecticides continued to build further year after year. In Turkey, the population of *T. absoluta* was found to be highly resistant to organophosphate, pyrethroid, indoxacarb, spinosad, chlorantranilprole and metaflumizone (Yalçın et al. 2015).

Studies on botanical pesticides have been conducted for many years and proofed high performance on controlling insect pests as well as reducing the negative impacts of synthetic insecticides (Adeyemi 2010). Fortuitously, various



plants contain compounds of insecticidal properties avail their use to manage various insect pests (Adeyemi 2010, Shrivastava and Singh 2014).

The use of botanicals; especially Neem *Azadirachta indica* which consists of Azadirachtin, a complex of tetranortri-terpenoid, indicated their efficacy as anti-feedant, toxic and repellent to *T. absoluta* without any incidence of resistance (Kona et al. 2014, Yalçin et al. 2015). In Sudan, many insecticides and three types of pheromones were recommended by the National Committee of Pests and Diseases to be used to control *T. absoluta* (Mohammed et al. 2013, Mahmoud et al. 2020). Intercropping of tomato plant with coriander was reported to reduce infestation of tomato by *T. absoluta* (Mahmoud et al. 2020). Laboratory experiments proofed that, the use of Neem seeds ethanoic extract and Jatropha (*Jatropha curcus*) seeds petroleum ether extract caused significant mortality to eggs and larvae of *T. absoluta* after 4 days (Kona et al. 2014). The insecticidal activities of aqueous extracts of five local plants (Neem *Azadirachta indica*, Garlic *Allium sativum*, Argel *Solenostemma sp.*, Coriander *Coriandrum sativum* and Khella *Ammi visnaga* (L.) plants reduced significantly the number of infested leaflets, the number of mines and the number of fruits infested by *T. absoluta* under greenhouse condition (Mahmoud et al. 2020). Due to development of pests' resistance, hazards to human health, adverse effects on environment and natural enemies, looking for safer alternative to insecticides is highly required. Sudan is a large country with diverse ecosystem contained big numbers of wild plants of medicinal values. Neem trees are widely grown for shade and as building materials which avail utilization of its products in medicine, cosmetics as well as in agriculture with free or low cost to poor communities. This study is a part of a program commenced to integrated management program to determine the impact of Neem seed oil, water extract of Datura and water extract of Vinca on *T. absoluta* as well as the effect of their use on yield of tomato compared to synthetic insecticide and untreated treatments.

## Materials and Methods

The experiment was conducted at the experimental farm of Kassala and Gash Research Station, (Takroof area), Kassala state, Sudan in the winter season of (2019/2020). The tomato accession HSD 10655 provided by Plant Genetic Resource Center of the Agricultural Research Corporation was sown in the nursery of the station in October prior to transplanted to the field in November. The land was ploughed, harrowed, leveled and allocated to plots measured (3x4m<sup>2</sup>) with two beds (Mastaba, 3x1.4m<sup>2</sup>). Plants were sown on both sides of the bed an intra row spacing was 0.6m and inter row spacing was 0.3m between plant holes. All cultural practices were followed as ARC standards.

### *Collection of Plant Materials and Preparation of Extracts*

Seeds of Neem *Azadirachta indica* A. Juss and leaves of periwinkle, *Vinca rosea* L., and Datura, *Datura stramonium*, L were collected from Kassala

Research Farm. Leaves of Vinca and Datura were dried under shade to prevent denaturation of active chemical compounds. Ten grams of powder leaves were soaked in 1 liters of water and then boiled for 20 minutes and left for 24 hours, then filtered with muslin cloth and kept as a stock solution for later use.

For extraction of Neem seed oil, Neem seed were soaked in water for 12 hours and were manually decorticated then left for 24 hours to dry under shaded area. Decorticated Neem seeds were pressed in local-made expeller to produce oil.

#### *Experimental Design and Field Observations on Infestation Levels, Active Mines on Leaves and Percentage of Damaged Fruits by T. absoluta*

A randomized complete block design (RCBD) was used to lay out the experiment which consisted of five treatments. Treatments were included Neem seed oil (0.72 L/ha), water extract of Vinca (0.96 L/ha) water extract of Datura (0.96 L/ha), Dancid15% EC (0.48 L/ha); standard chemical insecticide, and untreated as control. Each treatment was replicated thrice. All test materials were applied before sunset 3 times during the cropping season using pneumatic knapsack sprayer. Pre and post spray counts were conducted and data representing infestation parameters caused by *T. absoluta* were compiled during vegetative and harvesting periods include:

#### *Number of Tomato Infested Plants/Plot*

From each plot 20 plants were randomly selected and inspected for the presence of symptoms of *T. absoluta*.

#### *Number of Active Mines of T. absoluta on Leaves/Plant/Plot*

Number of active mines that contain live larvae of *T. absoluta* were determined by inspection of 5 leaves from 5 plants randomly selected from each plot.

#### *Percentage (%) of Fruits Damaged by T. absoluta*

On harvesting time, fruits were harvested and separated to damaged and healthy, the percentage of damaged fruits was calculated according to the following formula:

$$\% \text{ of infested fruits} = \frac{\text{No of infested fruits}}{\text{Total number of fruits}} \times 100\%$$

The three above mentioned parameters were assessed pre spray of test materials and also were assessed after 48h, 72h and week post spray.

#### *Yield Assessment*

Yield of tomato of different treatment (Ton/Ha) was calculated.

*Statistical Analysis*

Compiled data were analyzed using (SAS) statistical computer based package software version 9 and means were separated using Duncan's Multiple Range Test (DMRT).

**Results***Effect of Test Products on the Number of Infested Plants/Plot*1<sup>st</sup> Spray

Number of tomato plants infested by *T. absoluta* was significantly different between treatments after 48 hours, all test products were better than the control. Same results of reduction on number of infested plants was recorded for Neem seed oil, Water extract of Datura as well as Dancid® the chemical insecticides followed by water extract of Vinca. High significant difference was observed after 72 hours post spray in spite of increase of number of infested plants but the result was same for the four treatments including water extract of Vinca with average of 34.5 infested plants while the control reached 57.5 infested plants. After 7 days' number of infested plants was increased significantly compared to 48h and 72h. Untreated plots obtained highest number of infested plants (67.2plants/plot) while Plots treated with water extract of Datura generally were less infested followed by same effects on plots treated with Neem seed oil and Dancid® (the insecticide).

2<sup>nd</sup> Spray

As demonstrated in Table 1. High significant difference was observed between the number of infested plants/plot after 48h and 72h of the second spray. All test products reduced the number of infested plants/plot less than the control plots. Neem seed oil and WE of Datura were better fluctuated between 18.4 and 22.5 infested plants/plot in reducing the number of infested plants/plot than WE of Vinca and Dancid® (the insecticide). As in the first spray the number of infested plants was slightly increased in treated plots after 7 days (26-33plants/plot) when compared to very high number (75.4) of infested plants/plot recorded for the control. High significant difference was observed between the treatments. Effect of WE of Datura in infested plants/plot was comparable to that of Danicd followed by Neem seed oil and WE of Vinca.

3<sup>rd</sup> Spray

All test products reduced the number of infested plants/plot with significant differences between treatments for 48h, 72h and 7days post spray count. Water extract of Datura was the best product that reduced the number of infested plants/plot followed by Neem seed oil and then Dancid® and Vinca. After 7 days of the third spray, all test products were same in their effects and significantly reduced the number of infested plants/plot to (18 to 22) which is better than the control (82.1) infested plants/plot.

*Effect of Different Test Products on Active Mine of T. absoluta*1<sup>st</sup> Spray

In the first count significant difference was observed between treatments for pre spray count as well as for 48h, 72h and 7 days post spray. After 48 h of spray, WE of Datura gave better reduction in active mines (16.7) caused by larvae of *T. absoluta* followed by Dancid<sup>®</sup>, Neem seed oil and WE of Vinca with 19,21, 24.7 mines while the control recorded (28.3) mines (Table 2). After 72 h Neem seed oil, Dancid<sup>®</sup> and WE of Datura showed similar effect on the active mines which were less than the control. The number of mines 7 days' post spray was significantly same for all test products which were less than the control.

2<sup>nd</sup> Spray

In the second spray it was noticed that the number of mines decreased than its situation after 7 days in the first count. Significant differences were observed between treatments on the number of mines for 48h, 72h and 7days post spray. In all post spray counts, Plots treated with WE extract of Datura gave the lowest number of mines (mean=12) followed by Dancid<sup>®</sup> (mean=12), Neem seed oil (mean=15) and Vinca (mean=17) while the control recorded (mean=36) mines.

3<sup>rd</sup> Spray

High significant difference was observed between treatments on the number of mines for 48h, 72h and 7days of the 3<sup>rd</sup> post spray counts ( $Pr \geq F 0.0001$ ). The number of mines decreased gradually and successively according to time elapse for all test products while vice versa was reported for the control. Table 2 demonstrated same reduction effect of number of mines due to use of WE of Datura, Dancid<sup>®</sup> and Neem seed oil followed by WE of Vinca for the three post spray counts. Effect of test products on the percentage of tomato fruits infested by *T. absoluta*. Results displayed in Table 3 showed that there was significant difference between treatments on the percentage of fruit damage. Statistically equal reduction to the percentage of damaged fruits was recorded for WE of Vinca, Neem seed oil, Dancid<sup>®</sup>, WE of Datura ranged between 26.8 and 31.0% while the control recoded the highest fruit damage percentage (49.4%) according to the infestation by *T. absoluta*.

**Table 1.** Effect of Water Extracts of Wenca, Water Extract Datura, Neem Seed Oil and Dancid® on Mean Number of Plants Infested by *T. absoluta*/ Plot on Tomato Plants

Treatment	Pre-spray	1 <sup>st</sup> Post-spray			2 <sup>nd</sup> Post-spray			3 <sup>rd</sup> Post-spray		
		48hrs	72hrs	7days	48hrs	72hrs	7days	48hrs	72hrs	7days
Dancid®	40.9	32.7b	36.4b	38.2cb	29.0b	30.0b	26.0c	22.1cb	20.6b	18.4b
WE of Vinca	44.3	40.2 ba	37.1b	43.9b	31.9b	26.5cb	33.4b	25.8b	20.5b	22.0b
WE of Datura	40.5	29.5b	31.9b	36.03c	18.4c	20.8c	26.4c	14.4d	14.4c	19.2b
Neem seed oil	41.7	32.9b	33.5b	41.3cb	21.8c	22.5c	28.8cb	17.1cb	17.3cb	19.5b
Control	44.0	49.2a	57.5a	67.2a	53.7a	67.9a	75.4a	59.0a	71.0a	82.1a
C.V	11.0	16.2	7.6	7.0	11.8	10.6	7.3	14.0	10.5	9.0
SE±	1.12	2.23	2.66	3.1	3.4	4.7	5.1	4.4	5.8	6.7
Pr ≥F	0.6603	0.0517	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

**Table 2.** Effect of Water Extracts of Wenca, Water Extract Datura, Neem Seed Oil and Dancid® on Mean Number of Active Mines of *T. absoluta*/ Plot on Tomato Plants

Treatment	Pre-spray	1 <sup>st</sup> Post-spray			2 <sup>nd</sup> Post-spray			3 <sup>rd</sup> Post-spray		
		48hrs	72hrs	7days	48hrs	72hrs	7days	48hrs	72hrs	7days
Dancid®	24.0b	19dc	17.7c	19.0b	13.7dc	12.7c	12.7c	8.7c	8.0c	7.7c
WE of Vinca	28.8a	24.7b	25.3b	22.3b	21.3b	19.7b	17.7b	16.3b	13.7b	11.7b
WE of Datura	23.7b	16.7d	18.7c	20.3b	11.7d	12.7c	13.3cb	8.0c	8.0c	6.7c
Neem seed oil	28.2a	21.0c	20.3c	21.3b	16.0c	15.3cb	16.0cb	10.3c	9.7c	7.3c
Control	27.1a	28.3a	32.3a	36.2a	31.3a	36.3a	39.3a	34.3a	38.7a	45.3a
C.V	5.4	8.3	7.3	9.1	10.3	13.3	11.6	7.8	13.5	11.1
SE±	0.6	1.2	1.5	1.8	1.9	2.4	2.7	2.6	3.2	4.0
Pr ≥F	0.0123	0.0010	<0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

Note: WE= Water extract. Data with same letter are significantly equal.

**Table 3.** Effect of Water Extract of Vinca, Water Extract of Datura, Neem Seed Oil and Dancid® on (%) of Fruits Damaged by *T. absoluta*

Treatment	Fruits Damage (%)
Dancid®	28.03b
WE Vinca	26.8b
WE Datura	31.0b
Neem seed oil	27.1b
Control	49.4a
C.V	27.2
SE±	3.0
Pr≥F	0.0595

Note: WE= Water extract. Data with same letter are significantly equal.

#### Effect of Different Test Products Used to Control *T. absoluta* on Yield of Tomato

The obtained results of yield of tomato (Tons/hectare) due to the use of some products to control *T. absoluta* revealed high significant difference ( $Pr \geq F$   $0 < 0.0001$ ) between all test products and control. All test product improved yield 2 to 3 times better than the control. Neem seed oil obtained the highest yield (11.2 Ton/ha) among all test products followed by WE of Datura (9.9), Dancid® (9.7), WE of Vinca (8.8 Tons/ha) while the least yield (3.8 Tons/ha) was recorded to the control (Table 4).

**Table 4.** Effect of Application of Water Extracts of Vinca, Water Extract of Datura, Neem Seed Oil and Dancid® to Control *T. absoluta* on Tomato Yield (Tons/ha)

Treatment	Yield (Tons/hectare)
Dancid®	9.7b
WE Vinca	8.8c
WE Datura	9.9b
Neem seed oil	11.2a
Control	3.8d
C.V	4.2
SE±	0.6
Pr≥F	$0 < 0.0001$

Note: WE= Water extract. Data with same letter are significantly equal.

## Discussion

In the last seven decades many botanical formulations have proven to be potent and effective as many as conventional synthetic pesticides even at low concentrations. In fact, botanical insecticides have drawn great attention as major control agents in organic farming. However, their extensive uses have resulted in certain drawbacks and hazards, including, persistence, toxicity to non- target organism, pest resistance and environmental pollution (Siqueira et al. 2000, Lietti et al. 2005). Many studies have been focused on the use of botanical extracts includes oil, powder, ethanoic or aqueous extract for their effectiveness, cheapness, short persistence and low mammalian toxicity. Stoll (2000) and Hiiesaar et al. (2001) reported that many of plant materials show abroad spectrum of activities

against insect pests include lethal, anti-feedant, repellent and growth regulatory effects and Azadirachtin is well known effective botanical insecticide extracted from Neem plant (Mordue and Alasdair 2000). The tomato leaf miner, *T. absoluta*, a new pest in Sudan, has caused excessive damage to tomato in all parts of country since 2010 (Mahmoud et al. 2020).

In this study, the aqueous extracts of *Datura* and *Vinca* and Neem seed oil were applied to tomato plots infested by *T. absoluta* to determine their effect on number of infested plants/plot, active mines/plot and fruit damage/plot as well as their effect on yield of the crop. The results revealed significant difference among the test plant extracts compared to standard and control for three consecutive sprays for the above mentioned parameters. The results of using neem oil are in agree with findings of Coelho and Deschamps (2014) who stated the insecticidal and anti-feedant effect of neem on caterpillars of *T. absoluta*. Also the results of using neem oil is in accordance with findings of Illakwahhi and Srivastava (2019) who reported the potency of use of neem oil as insecticide and as synergist to increase activity of abamectin to control *T. absoluta* and reduce its resistance to abamectin. Study conducted by Tindade et al. (2000), reported that 84-100% control was achieved using different concentrations of Neem seed extract against young larvae of *T. absoluta*. On other hand, results of this study proved that plots treated with neem seed oil gained the highest yield, the same results of increasing yield due to use of neem seed oil was mentioned by Abbasi et al. (2003). Plots that's were treated by WE of *Datura* obtained similar results to Dancid® (the insecticide) in reducing the infestation of *T. absoluta* which is in accordance with findings of Buragohain et al. (2021) who stated similar reduction of the infestation of *T. absoluta* between neem extract and the standard insecticides without affecting the yield. In the current study, the effect of WE of *Datura* on reducing the number of infested plant/plot, number of active mines and percentage of infested fruits as well as increase yield was recorded which give the product the opportunity to be used as alternative to pesticides to control *T. absoluta* and increase yield of tomato crop (Habib et al. 2011). Abbasipour et al. (2011), reported that the seed and leaves extracts of *D. stramonium* are effective to control *Tribolium castaneum* while (Moreira et al. 2004) reported that, hexane and alcoholic extracts of *D. stramonium* had no insecticidal activity against larvae of *Diaphania hyalinata* (L.) (Lepidoptera: Pyralidae).

In spite of its effectiveness in controlling *T. absoluta*, *Datura* contains atropine, hyoscyamine, and scopolamine, which can produce poisoning with a severe anticholinergic syndrome which cause hallucinogenic and euphoric effects to human (Trancă et al. 2017). For the mentioned reasons further studies on residual effects of *Datura* is highly required. WE of *Vinca* is comparable to the insecticide in many post spray counts are comparable to other test products and much better than the control in the number of infested plant/plots and number of active mines and same as other test products on percentage of infested fruits. This results of *Vinca* is in agree with results of mortality and repellency caused by its powder and aqueous extracts against Faba bean beetle, *Bruchidius incarnates* (Boh.) under laboratory condition (Mohammed 2004).

## Conclusions and Recommendations

Use of Neem seed oil, WE of *Datura* and WE of *Vinca* as alternative to insecticides is effective to control *T. absoluta*. The extract of the three products reduced the number of infested plants/plot, number of active mines/plot as well as reduced the percentage of infested fruits and increased tomato yield.

Based on the above mentioned results, authors would like to recommend to the farmers use of Neem seed oil at (0.72 L/ha and use of WE of *Datura* and WE of *Vinca* at (0.96 L/ha) and for management of *T. absoluta*. Further studies for residual effect of WE of *Datura* is necessary and also preparation of formulations of the botanical extracts is required to encourage their use by farmers

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## Liquid Crystal Display (LCD) based Instruction and Physics Performance

By Bretel B. Dolipas<sup>\*</sup>, Freda Kate D. Samuel<sup>±</sup> & Kenneth B. Pakipac<sup>•</sup>

*The study determined the effectiveness of LCD based instruction to academic performance of students in physics concept, physics problem solving and overall physics performance. Respondents were third year students enrolled in the Physics subject under the course Bachelor of Science in Agribusiness. Result showed that both students with and without LCD instruction based instruction have above average performance level on physics concept and overall performance and an average performance in physics problem solving aspect. Male and female respondents also have same physics performance level on concept aspect, problem solving aspect and overall physics performance for both with and without computer-aided instruction. Conduct of similar research is recommended to confirm results of the study.*

**Keywords:** LCD, physics performance, sex, PowerPoint presentation, physics concept, problem solving

### Introduction

There are various teaching techniques used by teachers in the teaching-learning process. Usually the technique used is based on the applicability and effectiveness of the technique or method to impart the necessary learning competency to the student. One of these techniques is the LCD based Instruction, specifically using the power point presentation. The integration of such type of instruction offers a wide opportunity to the educational system with its capacity to enhance and integrate wide and meaningful information. It also allows students to have access to concepts beyond the classroom setting. LCD based instruction could be used to maximize student's participation as well as their understanding on concepts presented to them. This tool may aid students in their learning process by enabling them to understand abstract concepts through visualization. Also, LCD based instruction could transform the teaching process by providing aid to teachers because of its ease of use, flexibility and interactivity.

LCD based instruction with using power point presentations has become part of many instructional settings and is an alternative tool for learning, particularly in large classes and in courses more geared toward information exchange. It has the potential to transform the learning process by providing a new learning culture with the use of interactive slides, abstracts concepts can be presented with the aid

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of visualization, videos and or music can also be incorporated in the lesson process. Power point presentation also opens up various opportunities for learning because it enables students to access, transform and share information. PowerPoint presentation with the aid of LCD can be a highly effective tool to aid learning. It allows teachers to explain abstract concepts, while accommodating all learning styles. This tool may also serves as an avenue for collaborative learning and may enhance student's critical thinking, creative thinking and problem solving skills. Used properly, PowerPoint presentation can be one of the most powerful tools for disseminating information, but if not used carefully, may disengage students and hinder learning. It is in this concept that this study was formulated. Objectives of the Study:

One of the teaching techniques used to impart a concept to students is through LCD based instruction with the use of power point presentations. The focus of the study was to compare the performance of students who were taught of physics concepts with the use computer-aided instruction and students using the conventional textbook or hand-outs. The study also intends to compare the performance with the average. The following were the specific objectives of the study:

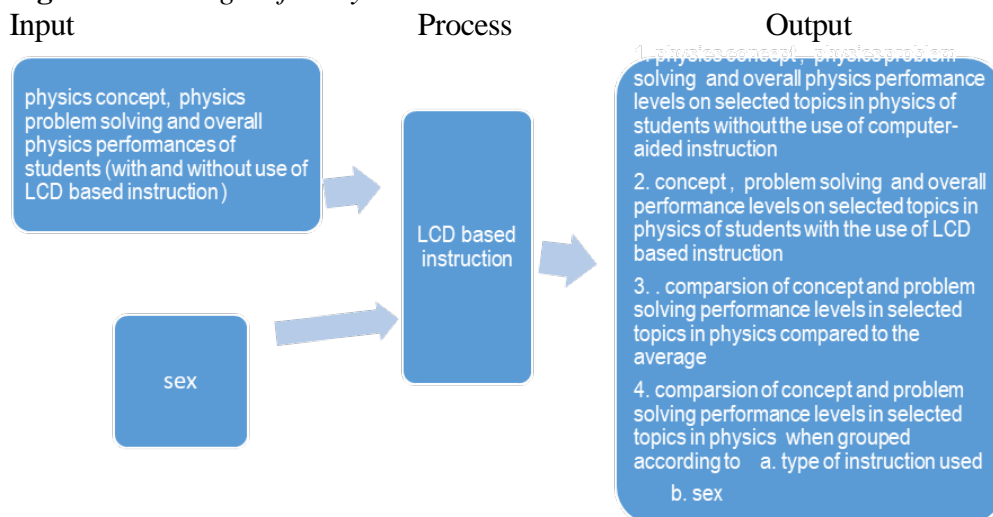
1. To determine the level of students' concept and problem solving performance in Physics without the LCD based instruction in the learning process.
2. To determine the level of student's concept and problem solving performance in selected topics on Physics with the use LCD based instruction in the learning process.
3. To compare the physics performance level on concept aspect, problem solving aspect and overall performance of students without computer-aided instruction when grouped according to sex.
4. To compare the physics performance level on concept aspect, problem solving aspect and overall performance of students with LCD based instruction when grouped according to sex.
5. To compare the level of student's concept, problem solving and overall performance in Physics with and without the use of LCD based instruction in the learning process

### *Conceptual Framework*

The teaching method used by instructors plays an important role in knowledge and skill acquisition of students. Most classrooms from pre-primary to tertiary institutions are dominated by the conventional method of teaching-learning method using chalkboards, marker-boards and handouts. The study of Iyengar et al. (2014) showed that the conventional method was ineffectiveness for very large group instruction. An inability to allow information storage for future use; and accommodate illustrations to support the teaching was also observed. The health hazard for teachers from chalk particles and it makes learning uninteresting are among the other limitations of the lecture method.

The goal of the study was to know the effect of using LCD based instruction specifically, power point presentation as a technique in the teaching learning process of students in mathematics and physics. Figure 1 shows the paradigm of the study.

**Figure 1. Paradigm of Study**



The independent variables were the students' concept and problem solving performance on selected topics in Physics 11; and student sex. From the independent variables, the concept and problem solving performance levels in selected topics in Physics 11; the comparison of the performance in Physics 11 of students compared to the average and when grouped according to learning using LCD based instruction and those with not.

#### *Hypotheses of the Study*

1. The student's concept, problem solving and overall physics performance level on selected topic in physics taught without using LCD based instruction is on the average.
2. The student's concept, problem solving and overall physics performance level on selected topic in physics taught with the use LCD based instruction is on the average.
3. There is no significant difference in physics performance level on concept aspect, problem solving aspect and overall performance of students without LCD based instruction when grouped according to sex.
4. There is no significant difference in physics performance level on concept aspect, problem solving aspect and overall performance of students with LCD based instruction when grouped according to sex.
5. There is significant difference in the overall performance level in on selected topic in Physics of students when grouped according to learning with or without the use of LCD based instruction.

## Literature Review

Different studies show that the use of technology in schools has developed new ways of teaching and learning. It enhances learning by providing a better understanding of the topic as well as motivating students.

The study of Zdaniuk et al. (2019) examined whether self-efficacy and gender influence the effect of PPT slide provision on academic performance. The result showed that there is no evidence for the provision of slide handouts to broaden, unconditional pedagogical value. Rather, it was found that both self-efficacy and gender moderated the extent to which the availability of the handouts enhanced or hindered students' performance. Also, both high self-efficacy and male students performed significantly better when they were provided with handouts. Students with low self-efficacy performed significantly worse when the handouts were provided. Lower performance was also observed for female students when provided with handouts. The result of the study also showed that students with PPT handouts perceived their instructor as more effective, and students felt more prepared. Lastly, it was observed that students considered the of PPT the handouts were more valuable to their learning and course performance than the one-to-one interactions with the professor

Gambari et al. (2015) determined the effectiveness of PowerPoint Presentation in teaching Technical Drawing concepts in Basic Technology. The study revealed that the students taught with Power Point presentation performed better than students taught with Chalk Board method. High achievers also performed better than medium and low achievers. The use of the Power Point presentations was also found to be gender friendly.

According to Bartsch and Cobern (2003), various colleges and universities have rooms equipped with technology necessary for any instructor to display information via PowerPoint presentations. They also emphasized in their study that students believed that they learned more from PowerPoint lectures. It was also shown in a study that students like to be taught using PowerPoint presentations (Craig and Amernic 2006).

Szabo and Hastings (2000) found to have positive attitudes toward PowerPoint lectures because they felt that PowerPoint lectures were interesting, able to get their attention, and help them to have better understanding. However, this did not reflect their achievement; both lecture styles had no significant differences on the students' test result.

Despite of the effectiveness of PowerPoint presentations to both teachers and students, they are one of the most easily misused teaching aids (Priya 2012). Greed (1997) argued about PowerPoint in several points: first, "you may get less feedback from the class because your eyes and theirs are on the screen rather than looking at each other;" second, students don't have a chance to synthesize what they've heard; and third, the emphasis is on the quality of your presentation rather than your students' learning.

Fedisson and Braidic (2009) made a study on the impact of PowerPoint presentations on student achievement and student attitudes. During instruction one class was taught using conventional methods of book work, hand-outs and lecture

and using Power Point for a second class. Result of the study showed that when using power point with the aid of LCD, student test grades increased

[Teofilo](#) et al. (2012) made a study on the effect of blended learning on academic performance on problem solving and programming of Bachelor of Science in Information Technology students. Result of the study showed that students with blended learning perform significantly better.

Cladellas Pros et al. (2013) studied the effects of the power point methodology on content learning. This study determined whether the use of PowerPoint technology as a method of transmitting information has an effect on students' learning compared with classes taught without this technology. The study included psychology students, divided into four groups, two of which were taught an ordinary Educational Psychology lesson with the only aid of the blackboard, while other two groups, a PowerPoint presentation was used to deliver the contents. Results showed significant differences with the scores of the groups without PowerPoint and the groups with PowerPoint. The use of technology can have a very positive influence on learning in a specific type of learning.

An examination was done by Bernardo and Bay (2013) on the technology-driven teaching strategies used in Photojournalism course in Lyceum of the Philippines University-Batangas. The study determined the frequency of use, the effectiveness and the problems encountered by the students during the execution of the technology-driven teaching strategies used. The results showed that the effectiveness of the technology-driven teaching strategies depends on how frequently they are used in the class, while effectiveness is not affected by the problems encountered.

Lari (2014) determined the impact of using Powerpoint presentations on students' learning and motivation in the secondary school English (TEFL) process. The subjects were split into two groups, (Experimental and Control). Each group was taught differently, one using technology like video-projector, power-point, in class; and the other through a traditional method such as the use of textbooks. Result showed teaching based on the use of technology had a significant positive effect on learners' scores. Analyses showed that the experimental group learners performed better than the control group.

Enriquez (2014) made a study on students' Perceptions on the Effectiveness of the Use of Edmodo as a Supplementary Tool for learning social science courses. The findings affirmed that majority of participants considered Edmodo as an effective supplementary tool for their learning.

Balmeo et al. (2014) made a study on integrating technology in teaching students with special learning needs in the SPED Schools in Baguio City. The research focused on integration of technologies in the educational environments where students with special learning needs are housed. It determined the availability and effectiveness of technology in the classroom and determined encountered problems in the technology integration. Result showed that there were limited level of availability and effectiveness of technology.

Aquino (1986) as cited by Calisog (2010), and Teofilo et al. (2012) said that teaching is the act of providing activities that facilitates learning. It is the process where gaining knowledge and learning takes place. There are many techniques or

methods used in the teaching-learning process by teachers. The technique or method used is usually based on the applicability and effectiveness of the technique or method to impart the necessary knowledge to the student. Computer-aided instruction like PowerPoint using **LCD** has become part of many instructional settings and is an alternative tool for learning, particularly in large classes and in courses more geared toward information exchange. PowerPoint can be a highly effective tool to aid learning. PowerPoint can be one of the most powerful tools for disseminating information, but if not used carefully, may disengage students and hinder learning. PowerPoint could potentially confuse students and make learning a difficult process. It is in this concept that this study was formulated.

Based on the result of the study of Tagle (2007), lecture was the most utilized instructional method in teaching by the teachers. Demonstration and problem solving methods are the other methods commonly used. Benguet State University is among schools which make use of lecture method. Hence, it is necessary to consider if the use of other techniques like LCD based instruction will make a significant improvement on students' academic performances.

### *Significance of the Study*

It was hoped that the output of this study would show the technology effect to physics performance level of students. The result of the study would provide relevant information to the faculty of the College about the learner to help the teacher select appropriate strategies, methodologies and the type of instructional materials to be used that would arouse the intellect of the students. It is also hoped that the results of this study could contribute to the research literature in the field of education in general and the improvement of physics instruction in particular.

## **Methodology**

### *Respondent and Place of Study*

The respondents of the study were students enrolled in selected physics subject under one of the researcher Physics classes at Benguet State University, La Trinidad, Benguet.

The researchers utilized complete enumeration on each class. Specifically, two Bachelor of Science in AgriBusiness classes where the respondents three males and twenty four females in the experimental group while there were four males and thirty two females in the control group.

### *Research Method*

The study is a descriptive causal quantitative research which makes use of purposive sampling technique.



### *Instrumentation*

Students were taught of Physics concept on Mechanics using power point presentation with the aid of LCD for one group and another group of students were taught of the same concept using the conventional method of instruction. To avoid other possible intervening factors, two classes of the same year level and same course and subject of each researcher were utilized. A respondent homogeneity test was also conducted and affirmed homogeneity of respondents. A teacher-made exam was given to the students before the conduct of the study to randomize the proper distribution of students according to group. Each group was divided into groups as experimental or control group. The same formulated test was given to the two groups to measure the corresponding performance. Comparison of performance for the two groups was done.

### *Statistical Analysis*

The performance in Physics was grouped into two categories: the concept category and the problem solving category.

The mean was used to determine the categorized performance level of in physics of students with the following scale:

93 or Above	High Performance	H
84 – 92	Above Average Performance	AA
75 – 83	Average Performance	A
66 – 74	Below Average Performance	BA
65 or below	Poor Performance	P

The t-test was used to compare the performances of the students taught using computer-aided instruction and with the control group. One-Sample t test was used to compare level of performance compared to the average. All tests were done at 0.05 level of significance.

## **Results and Discussion**

### *Level of Performance of Students in Physics without the LCD based Instruction*

Table 1 presents the level of physics performance of students who did not use the LCD based Instruction. Analysis showed that the level of performance of students in concept was above average with a mean of 84.85. Specifically, 57.50% of the respondents had either high or above average performance in physics concept, while 42.5% either average or below average performance in physics. On the other hand, the level of performance of students in problem solving was average as presented by the mean of 81.99. Among the students, 45.50% of the students have average performance while the 30.30% have either above average or

high performance level and the remaining 8% performed either below average or poor.

**Table 1.** Level of Performance of Students without the Use of LCD based Instruction

Level	f	%	Mean	D.E.	p-value
Concept					
High	1	3.00	84.85	AA	0.000**
Above Average	18	54.50			
Average	9	27.30			
Below Average	5	15.20			
Problem Solving					
High	4	12.10	81.99	A	0.063 <sup>ns</sup>
Above Average	6	18.20			
Average	15	45.50			
Below Average	7	21.20			
Poor	1	3.00			
Overall					
Above Average	16	48.50	83.56	A	0.000**
Average	17	51.50			
Total	58	100.00			

Overall, the performance of the students was average with a mean value of 83.56. However, analysis revealed that the level of performance of students who did not use LCD based Instruction is significantly different from average with a p-value of 0.000. Thus, the hypothesis is rejected. This simply suggests that the level of performance of students who did not use Computer-Aided Instruction is higher than average. Result show that 51.50% of the respondents had average performance while 48.50% have above average performance but the variance in performance level in the concept and in problem solving lead to a mean that is significantly higher than the average. This indicates that the traditional method of teaching learning process is still effective method in the transfer of knowledge to students. This is both true for concept aspect and problem solving aspect in physics.

#### *Level of Performance of Students in Physics with the Use of LCD based Instruction*

Table 2 presents the performance level in physics of students who undergone the learning process in physics with the use of LCD based instruction. Using the Likert scale, the computed mean values of 82.36%, 81.78% and 82.10% for concept aspect, problem solving aspect, and overall performance, respectively, implies all performance level are on the average. However, further comparison to the average at 0.05 level of significance, and presented by the p values of 0.002, 0.0099, and 0.006, respectively for concept component, problem solving component, and overall performance, the concept and overall performance is above average while the problem solving aspect performance is on the average.

**Table 2.** *Level of Performance of Students without the Use of LCD aided Instruction*

Area	f	%	Mean	D.E.	p-value
Concept					
Above Average	11	44.00	82.36	A	0.002**
Average	12	48.00			
Below Average	2	8.00			
Problem Solving					
High	2	8.00	81.78	A	0.099 <sup>ns</sup>
Above Average	6	24.00			
Average	12	48.00			
Below Average	5	20.00			
Over – All					
Above Average	11	44.00	82.10	A	0.006**
Average	13	52.00			
Below Average	1	4.00			
Total	58	100.00			

The result indicates that computer-aided instruction is likewise an effective method to be used in the teaching learning process not on just on the impart of concept but also in the problem solving aspect.

The result from Table 2 shows a similar result with students who did not used the computer aided instruction as presented in Table 1. This implies that in imparting knowledge be it concept or problem solving aspect, the traditional way and LCD based instruction are both effective. This result is supported by the study of Daniels (1999) which showed the effectiveness of computer-aided instruction in a tertiary level economics class and found no significant difference in student performance showed that there was no evidence that PowerPoint can enhance students' performance.

#### *Difference on the Performance of Students when Compared According to Sex*

Table 3 presents the comparison of performance level in physics without the use LCD based Instruction when students are grouped according to sex. The computed mean values gave difference in performance level along concept and overall performance for male and female. While on problem solving aspect, both male and female have above average performance level. Further testing though, showed p values which were not significant at 0.05 level of significance. This implies that there were no significant differences on the level of performance along concept, problem solving and on the overall of male and female students who did not use LCD based Instruction. Hypothesis is therefore rejected.

**Table 3.** Level of Performance of Students without the Use of LCD based Instruction when Compared According to Sex

AREAS	Male		Female		p-value
	Mean	D.E.	Mean	D.E.	
Concept	89.17	AA	83.00	A	0.055 <sup>ns</sup>
Problem Solving	89.39	AA	84.39	AA	0.111 <sup>ns</sup>
Over-All	85.19	AA	81.67	A	0.522 <sup>ns</sup>

Table 4 shows the comparison of performance level on physics along concept, problem solving and on the overall with LCD Based Instruction when students were grouped according to sex. As indicated by the computed mean values which were categorized as average performances based on the Likert scale used, the performance level along concept, problem solving and on the overall performance of both male and female are on the average. Further testing as presented by the p values computed confirms that the performance level in physics are not significant when grouped according to sex.

**Table 4.** Level of Performance of Students with the Use of LCD based Instruction when Compared According to Sex

AREAS	Male		Female		p-value
	Mean	D.E.	Mean	D.E.	
Concept	81.82	A	82.44	A	0.655 <sup>ns</sup>
Problem Solving	83.33	A	81.57	A	0.839 <sup>ns</sup>
Over-All	80.83	A	82.27	A	0.731 <sup>ns</sup>

#### *Difference on the Physics Performance of Students when Compared According to Method used*

Table 5 presents the comparison of physics performance level on concept and problem solving aspect of students grouped according to method used in the teaching learning process. Based from the computed p values which were not significant at 0.05 level of significance, there were no significant differences on the level of performances of student in physics when compared according to the teaching method used. This simply suggests that students who used LCD Based Instruction have the same performance level with students who did not use LCD Based Instruction.

**Table 5.** Level of Physics Performance of Students when Compared According to Method

AREAS	Without LCD Based Instruction		With LCD Based Instruction		p-value
	Mean	D.E.	Mean	D.E.	
Concept	84.85	AA**	82.36	A**	0.297 <sup>ns</sup>
Problem Solving	81.99	A <sup>ns</sup>	81.78	A <sup>ns</sup>	0.067 <sup>ns</sup>
Over-All	83.56	A**	82.10	A**	0.927 <sup>ns</sup>

For students who did not use computer aided instruction, table 1 showed that the performance level on concept and overall physics performance are above average while average performance level is observed on the problem solving aspect. Same result is presented on table 2 showing the same performance levels on the concept, problem solving and overall performance for students with LCD based Instruction. Table 5 confirms the said similar results and indicated that indeed, students both with or without LCD based instruction have above average overall physics performance level and on the concept aspect. Average performance level is observed on the problem solving aspect for both group. This confirms that the conventional and LCD based instruction are both effective teaching method in imparting physics knowledge. Similar result was shown by the study of Fedisson and Braidic (2009) on 2<sup>nd</sup> level student achievement. Incorporating LCD-aided instruction does not show significant difference in the performance level with those who utilized the conventional method of text book and chalk board way of teaching. Study of Balmeo et al. (2014) likewise showed similar result. Similarly, Savoy et al. (2009), Apperson et al. (2006) Beets and Lobingier (2001), Susskind (2005), and Szabo and Hastings (2000) found little effects of PowerPoint on students' academic achievement; more than the traditional lectures.

## Conclusion

Based on the results of the study, the following are concluded:

1. The performance level in the problem solving aspect of physics is average, while the performance level on the concept and also overall physics performance level are both above average for student not using LCD based instruction.
2. The performance level in the problem solving aspect of physics is average, while the performance level on the concept and also overall physics performance level are both above average for student using LCD based instruction.
3. The physics performance level on concept, problem solving aspect and overall performance of both female and male students who had no LCD based instruction, do not differ significantly.
4. The physics performance level on concept, problem solving aspect and overall performance of both female and male students who had LCD based instruction, do not differ significantly.
5. Students' physics performance level on the concept aspect, problem solving aspect and overall performance do not differ significantly when grouped according to method of instruction used.

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