3D Models of Korat Dinosaurs: Integrating Paleontological Research to Persuasive Impact on Education and Learning for Youth

Duangsuda Chokchaloemwong[1,2*]

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Abstract

The understanding of paleontology by conveying the imaginary content in the academic aspect of the paleontologist resulted in many research studies to compile datasets and research materials of paleontologists. Using computer-based reference programs can effectively enhance one's knowledge of paleobiology. The highly-regarded 3D modeling and animation software (Blender) has recently expanded its selection with an exceptional array of over 100 new crystallographic educational models. Over the last ten years, Thailand has uncovered a variety of non-marine fossil vertebrates from the Mesozoic era. These discoveries date back to the Late Triassic period and extend to the late Early Cretaceous. One of the intriguing findings includes dinosaur remains, specifically iguanodontian ornithopods such as *Ratchasimasaurus suranareae*, *Siamodon nimngami*, and *Sirindhorna khoratensis*, all from the Lower Cretaceous Khok Kruat Formation in Nakhon Ratchasima Province. Additionally, a Carcharodontosaurid known as *Siamraptor suwati* has also been identified. In this study, these dinosaurs will be generated in virtual animations, allowing scientists to study and represent them as they live today. Next, Test printing the 3D models of anatomical replicas. The potential of 3D models of dinosaurs for education and museum displays is immense. These models enable students and visitors to closely examine these extinct creatures' detailed anatomical features and better understand their size and physical characteristics. Furthermore, the use of augmented reality can greatly enhance our knowledge of biology and ecology, making these models a valuable tool for scientific research and education.

Keywords: Korat Dinosaur, 3D Model, Augmented Reality

[1] School of Science Education, Faculty of Science and Technology, Nakhon Ratchasima Rajabhat University, Nakhon Ratchasima 30000, Thailand

[2] Northeastern Research Institute of Petrified Wood and Mineral Resources, Nakhon Ratchasima Rajabhat University, 184 Moo 7 Suranaree Subdistrict, Mueang, Nakhon Ratchasima 30000, Thailand

[*]Corresponding Author E-mail: duangsuda.c@nrru.ac.th

Introduction

In Thailand, Dinosaur was found in the north-eastern plateau, "Khorat Plateau". It is the land of origin of sauropod (plant-eating) and theropod (meat-eating) dinosaur, which later evolved and distributed to other territories. The evidence was from a sauropod remains, *Isanosaurus attavipachi* which was 210 million years ago (MYA) in age and was found in Chaiyaphum province. This fossil is older than the other sauropods fossils that were previously found in the world. Moreover, tyrannosaurid theropod fossils, *Siamotyrannus isanensis* (130 MYA) were found in Khon Kaen province. It was recognized as the world's oldest tyrannosaur compared with other tyrannosaurs, which are not over 100 million years old. *Siamosaurus suteethorni* is the first spinosaurid dinosaur (130 MYA). A complete sauropod skeleton in Thailand is *Phuwiangosaurus sirindhornae* (130 MYA) found in Kalasin province. The first Ceratopsia was *Psittacosaurus satayaraki* (100 MYA) that found in Chaiyaphum province. Nakhon Ratchasima province (Korat) was once home to three types of dinosaurs. The southwestern part of the Khorat Plateau, particularly the Suranaree and Khok Kruat subdistricts in Nakhon Ratchasima province. Iguanodontian ornithopods have been described based on isolated remains, described as *Siamodon nimngami*, *Ratchasimasaurus suranareae*, and *Sirindhorna khoratensis.* Moreover, a new theropod taxon is described based on extensive cranial and post-cranial materials described as *Siamraptor suwati.* All four dinosaur materials were collected in a locality of the Khok Kruat Formation, Lower Cretaceous 115 MYA (see Figure 1).

Paleoart allows people to connect with the deep history of life on Earth through a challenging art form that requires an understanding of anatomy, biology, and the ability to realistically depict a variety of textures and environmental details, as well as behavior and ecology. Currently, paleontologists in Thailand are conducting research on dinosaurs, which includes paleontology studies, the morphology of excavated fossils, and the source of dinosaur skeletons. However, there is a lack of research on simulating dinosaurs' anatomical and physiological structures based on bone mass analysis, size, and body proportions. To address this, paleontologists need to use their imagination to hypothesize what these dinosaurs looked like when they were alive. This approach can be integrated into science and used to produce computer graphics to create a scientific model known as paleoart. This research connects knowledge and integrates it with the science of paleontology, resulting in research-oriented findings that will positively impact education and learning for individuals interested in this field.

Drawing, describing, and identifying fossil specimens are the most fundamental skills in paleontology. These skills are essential for studying the fossil record and comprehending the evidence it provides about the evolution of life over time (Cunningham, 2021). Over the past two decades, technological advancements in computer-aided visualization have led to a digital revolution in paleontological research. This has made it possible to create digital models of fossils using various scanning technologies, which can be easily shared and studied. Photogrammetry is a particularly relevant technology for education, as it enables the production of photo-realistic 3D digital models. Photogrammetry involves taking overlapping photographs of a fossil and converting them into a 3D digital model that the user can manipulate (Bates et al., 2010; Falkingham, 2012; Cunningham, 2021).

However, in the past, even though we could simulate the primordial conditions and appearance of dinosaurs discovered through drawings 2 dimensions (2D) which may be challenging to understand and stimulate awareness. Reach out to young people interested in virtual media. Therefore, the extension of basic research led to the creation of this virtual 3D dinosaur model innovation. It will be an extension of the original knowledge we came from. Creating work to apply for copyright registration leads to income generation in developing souvenir products to develop identity products the identity of Nakhon Ratchasima province.

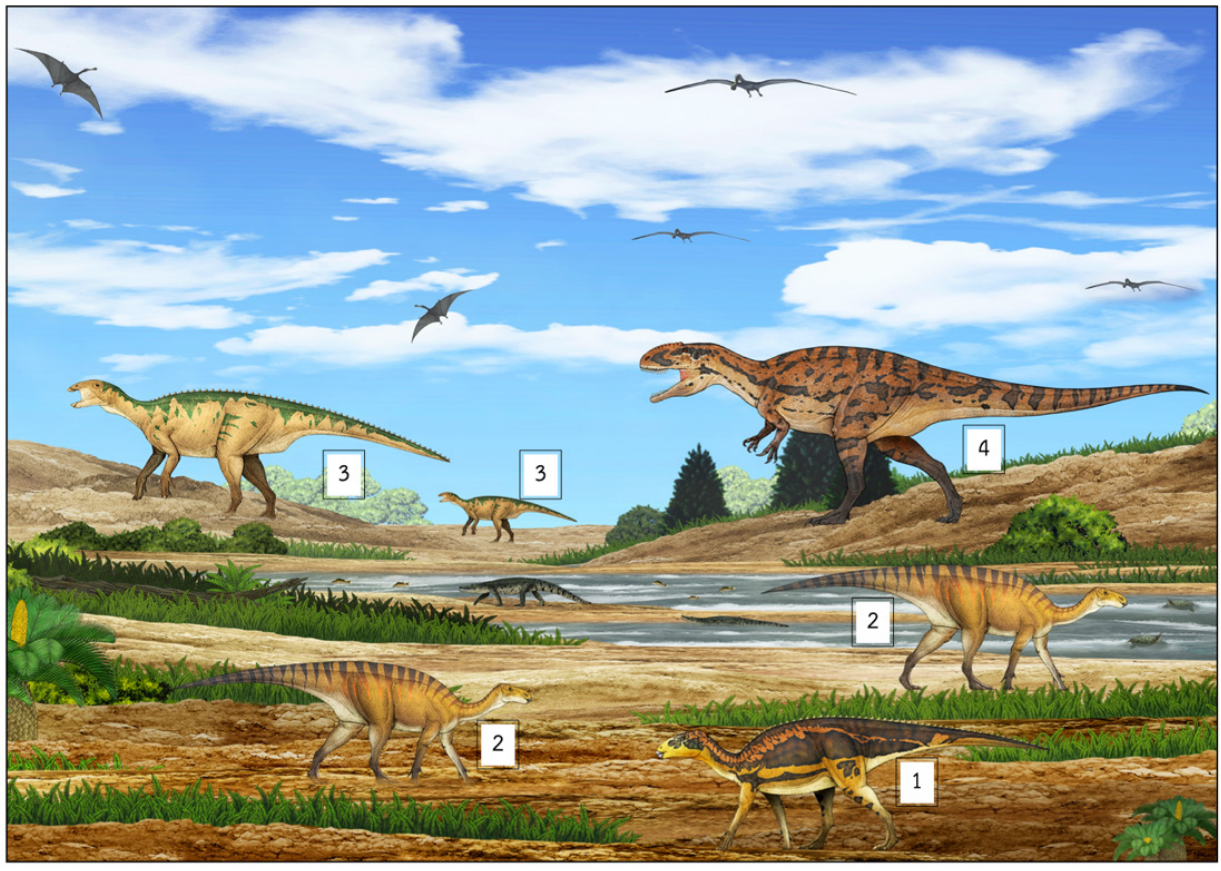

Figure 1. The reconstruction of the paleoenvironment in Nakhon Ratchasima (Lower Cretaceous, 115 MYA) *Siamodon nimngami* (1) *Ratchasimasaurus suranareae* (2), *Sirindhorna khoratensis* (3), and *Siamraptor suwati* (4) dinosaurs.

Research Methodology

This study analyzes the qualitative findings of an in-depth interview and evaluation assessment (Macmillan, 1971). Information was gathered from key informants, including researchers, academic staff, and museum staff who contributed to the production of Korat Dinosaurs. Data was collected through document analysis and group discussions. Figure 2 displays the methodology used in conducting this research.

Results and discussion

This research conducts one-on-one in-depth interviews with researchers who specialize in four dinosaur species, consisting of 1) *Ratchasimasaurus suranareae*, 2) *Siammodon nimngami*, 3) *Sirindhorna khoratensis* and 4) *Siamraptor suwati* to sketch these dinosaurs by 2D. After that, a 2D sketch will be used to create a 3D object design using Blender free software program. The process of the research is shown in Figures 2, 4, and 5. Results of the research project on the development of the 3D Korat dinosaur model started with the researcher having compiled relevant research documents about all four Korat dinosaurs, comprising *Ratchasimasaurus suranareae*, published work by Shibata et al. (2011), *Siammodon nimngami* published work by Buffetaut and Suteethorn (2011), *Sirindhorna Khoratensis* published work by Shibata et al. (2015) and *Siamraptor suwati*, published work by Chokchaloemwong et al. (2019). The process of research methodology is shown in Figures 3 and 5. After identifying the left maxilla bone (upper jaw) of *Sirindhorna khoratensis* in Figure 3 (1), it is vital that create a 2D true-scale replica of the skull Figure 3 (2)-(3) and the entire dinosaur body by sketching and painting in Figure 3 (4). From there, the next step is to produce a 3D model of *Sirindhorna khoratensis* using Blender software in Figure 3 (5). Testing the 3D model by printing and coloring the final object is critical to ensure its accuracy and precision. This process requires no shortcuts Figure 3 (6).

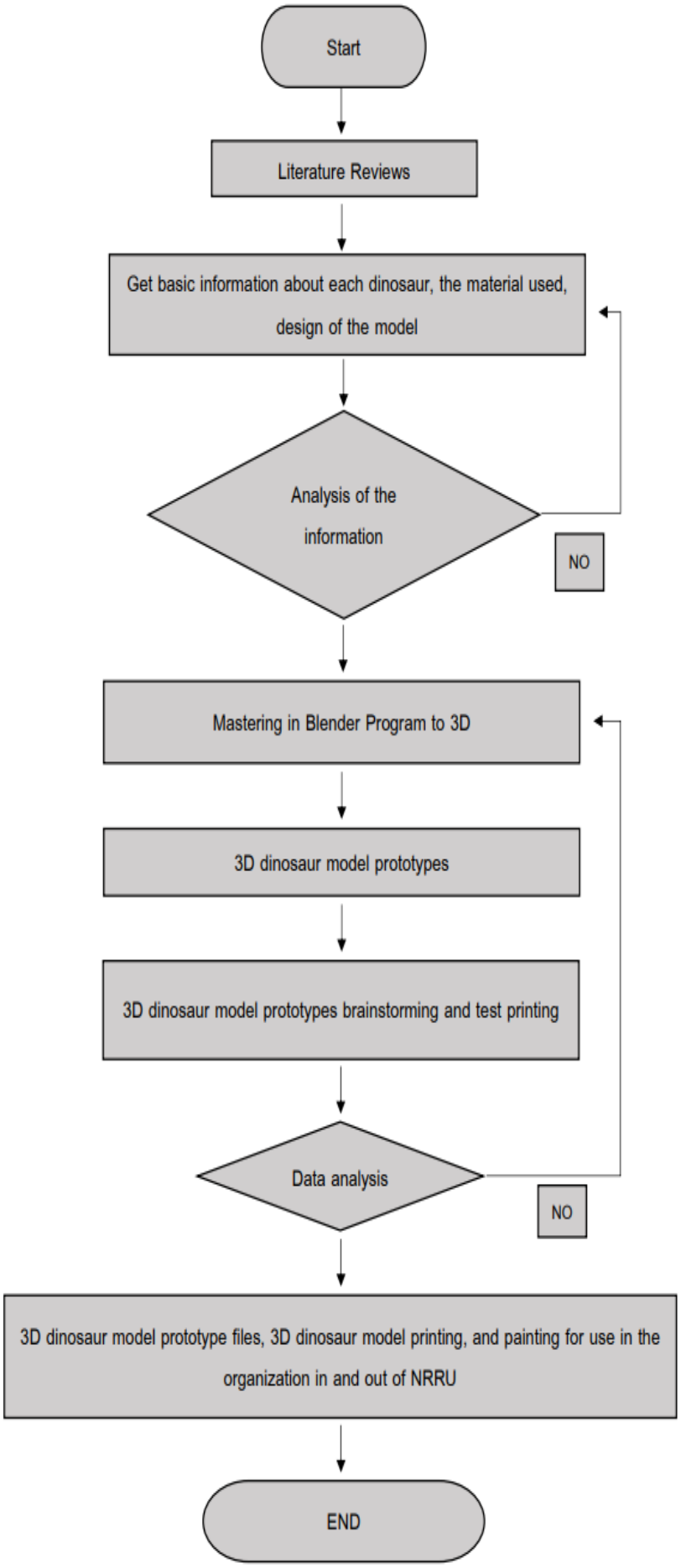

Figure 2. The flowchart of the study.

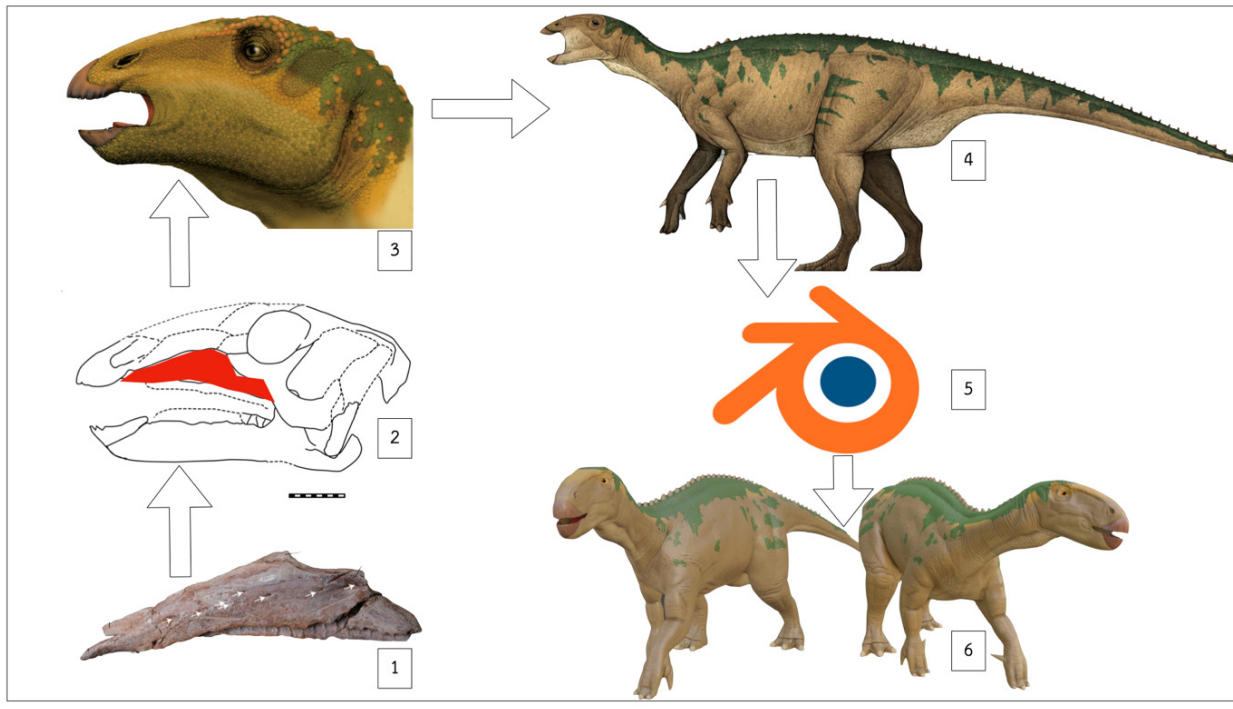

Figure 3. Overview of the research methodology.

Ratchasimasaurus suranareae is an iguanodontid dinosaur discovered in 2011. The holotype specimen is a lower jaw, dentary on the left side with toothless (see Figure 4A). *Siammodon nimngami* is also found in 2011. The *Siammodon nimngami* holotype is a well-preserved left maxilla (Figure 4B), although its anterior and posterior ends show signs of abrasion and may be incomplete. It shows a triangular outline, with the apex of the triangle (formed by the dorsal process of the maxilla) nearly equidistant from the anterior and posterior ends of the bone (as preserved). The anterodorsal margin of the maxilla bulges slightly dorsally. The ventral margin of the maxilla is slightly concave in lateral or medial view, and nearly straight in ventral view, except in its posteriormost part, where it curves slightly laterally. The tooth row is only partly preserved. In contrast, although two iguanodontians have known from the Lower Cretaceous of Thailand, *Siammodon nimngami* and *Ratchasimasaurus suranareae*, none of them provides enough characters to discuss their phylogenies in detail. In 2015, Shibata et al. (2015) described the new taxon is known from extensive remains, including a disarticulated skull and mandibles, and is much more complete than the material of the aforementioned Thailand iguanodontians named *Sirindhorna Khoratensis*. The almost-completed *Sirindhorna Khoratensis* skull parts (Figure 4C) help us to create the model of three iguanodontian dinosaurs that we found in the Mueang district of Nakhon Ratchasima province. Two hadrosauroids iguanodontian dinosaurs have been previously known from the Khok Kruat Formation: *Siammodon nimngami* (Buffetaut and Suteethorn 2011) and *Ratchasimasaurus suranareae* (Shibata et al. 2015). *Siammodon nimngami* was based upon an isolated maxilla. The isosceles-shaped maxilla of *Siammodon nimngami* is distinct from the low triangle shape of *Sirindhorna khoratensis*. On the other hand, *Ratchasimasaurus suranareae*, is known only from one dentary, characterized by a low and elongated dentary ramus and the robust coronoid process. The morphology of *Ratchasimasaurus suranareae* is unique among iguanodontians and is distinguishable from that of *Sirindhorna khoratensis*. Consequently, *Sirindhorna khoratensis* is regarded as a valid genus and species. Even though lacking information on the whole skeletal body of these iguanodontian hadrosauriforms were diversified in the Early Cretaceous of Asia, especially, from the Barremian-Albian stages parallel with the Khok Kruat Formation. For instance, the comparison with *Fukuisaurus*, *Koshisaurus* from Japan, and *Bolong* and *Jinzhousaurus* from China were all found in Barremian - early Aptian stages. Later on, the Asian basal hadrosauroids are mainly dis-

covered from Aptian-Albian stages: *Altirhinus* from Mongolia, *Jintasaurus*, *Xuwulong*, *Equijubus*, and *Gongpoquansaurus*, from Gansu Province and *Probactrosaurus* from Inner Mongolia, China. Currently, we possess three forms of Thailand's hadrosaurids found in the Khok Kruat Formation during the Aptian period. Additional fossil records and geological investigations are needed to resolve dinosaur paleobiogeography in Thailand. All the data is used to compare and develop 2D files of these three iguanodontian dinosaurs (Figure 3-4).

Siamraptor suwati is an the first carcharodontosaurid dinosaur is found in Nakhon Ratchasima in 2019 (Chokchaloemwong et al., 2019). This new taxon is based on a composite cranial and postcranial skeleton comprising the premaxilla, maxilla, jugal, surangular, prearticular, articular, vertebrae, manual ungual, ischium, tibia, and pedal phalanx see in Figure 5 (1). It is distinguished from other allosauroids by characters such as a jugal with a straight ventral margin and dorsoventrally deep anterior process below the orbit, a surangular with a deep oval concavity at the posterior end of the lateral shelf, and four posterior surangular foramina, a long and narrow groove along the suture between the surangular and the prearticular, an articular with a foramen at the notch of the suture with the prearticular, an anterior cervical vertebra with a pneumatic foramen (so-called 'pleurocoel') excavating parapophysis, and cervical and posterior dorsal vertebrae penetrated by a pair of small foramina bilaterally at the base of the neural spine. A significant skeletal pneumatic system was found in this new taxon, comparable to other carcharodontosaurians, due to the presence of many camerae and pneumatopores in cranial and axial elements. The information of fossils that we found, was used and compared with other carcharodontosaurian dinosaurs for reconstruction 2D, see Figure 5 (2). However, those taxa could have another phylogenetical interpretation as tyrannosaurids. Both phylogenetic analyses using two independent datasets locate *Siamraptor suwati* as the most basal member of Carcharodontosauria. This also means that this taxon is Southeast Asia's first definitive carcharodontosaurian theropod. *Siamraptor* is the best preserved carcharodontosaurian theropod in Southeast Asia, and it sheds new light on the early evolutionary history of Carcharodontosauria. After The drawing created of 2D *Siamraptor suwati* correlated with the fossil that found the estimated size of the body. Then skin and color depend on the idea of the researcher that the layer of skin is from the color of the rock in the Ban Saphan Hin excavation site see Figure 5 (4-6), and Figure 6D.

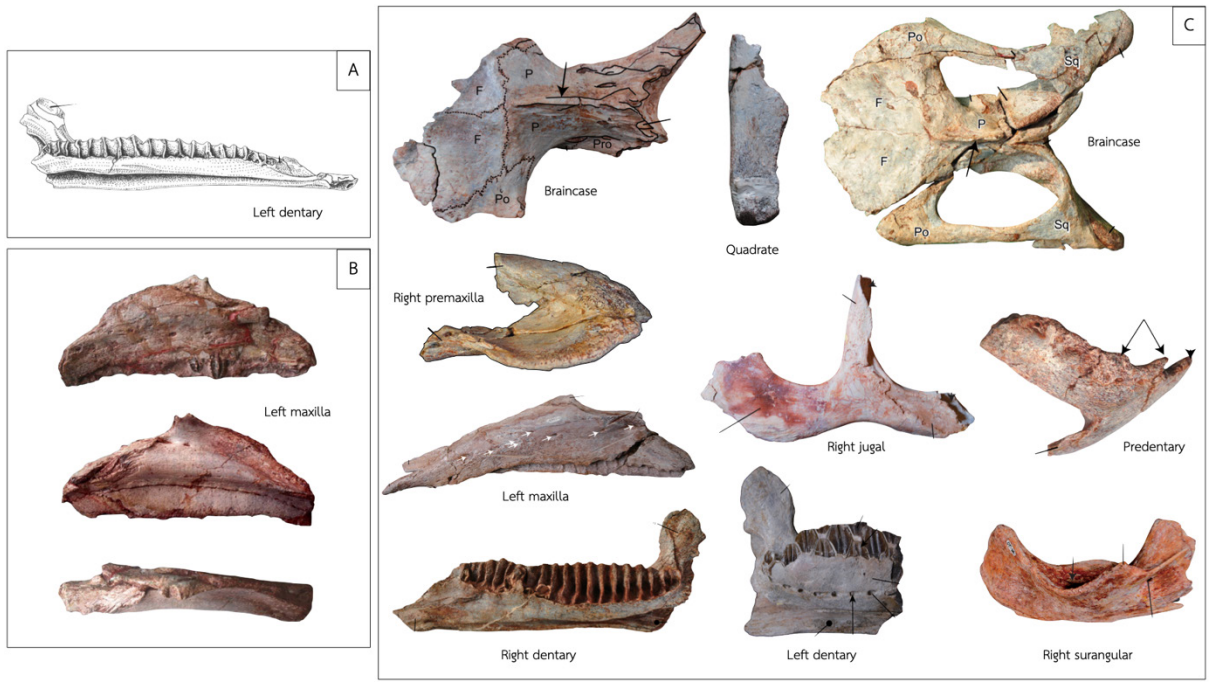

Figure 4. The fossils of *Ratchasimasaurus suranareae* (A), *Siammodon nimngami* (B), and *Sirindhorna khoratensis* (C) photos adjusted from Buffetaut and Suteethorn 2011; Shibata et al. 2011; 2015

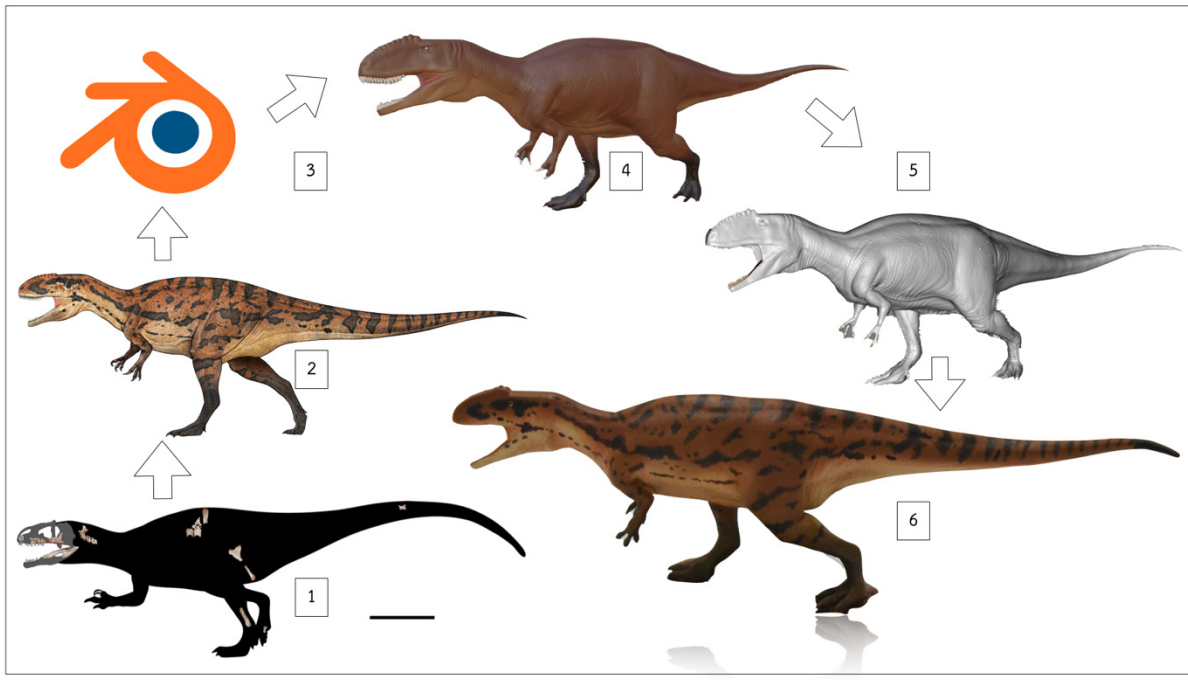

Figure 5. The fossils of *Siamraptor suwati* (1) and the process of 3D model creation (2-6).

Figure 6. The 3D dinosaur printing and coloring prototype of *Ratchasimasaurus suranareae* (A), *Siammodon nimngami* (B), *Sirindhorna khoratensis* (C), and *Siamraptor suwati* (D) dinosaurs.

In terms of design, all four species of Korat dinosaurs have been created as 2D images and 3D models until the prototype is fully colored with the model base (Figure 6). A satisfaction survey was conducted for the general public, and the results showed that most respondents were highly satisfied with the prototype model. Regarding model design, the 3D dinosaur models are academically accurate and have high resolution. The 3D dinosaur models contrast adds novelty to the model using modern techniques. The 3D dinosaur models aid in visualizing the museum's identity and have practical applications for product design. The dinosaur

Figure 7. The use of 3D dinosaur model files to generate AR code.

model facilitates visualization and practical applications. It can be recommended and used in product design for future benefits.

Moreover, this research aims to bring 3D dinosaur models to interact with people by creating AR code (Figure 7). All of these models are free to view in a web browser or through a smartphone application. Additionally, all of these models are freely downloadable through the supporting information and Sketchfab, and users are encouraged to download and modify these models to best suit their needs. This library of models is part of the authors' ongoing outreach program to provide 3D models for free for educational purposes, and the authors offer their services to create additional models and moderate this library as additional requests or critiques are provided. Skarbez et al. (2022) said that AR usage is increasingly social; as such, future research needs to consider not only the individual user's experience of a system but perhaps the social and cultural effects associated with that system. Moreover, looking to research in the social sciences for inspiration, methods, and measures will be a fruitful endeavor for a field that has historically been led by computing scientists and engineers.

Conclusion

The design and development of dinosaur models that fossils were found in Nakhon Ratchasima Province, including *Ratchasimasaurus suranareae*, *Siamodon nimngami*, *Sirindhorna khoratensis,* and *Siamraptor suwati*. In terms of design, all four species of Korat dinosaurs have been designed, which started with a 2D image sketch and then produced 3D model files until the prototype was printed. The model is completely colored with the model base. The general public surveyed satisfaction with the prototype model. The satisfaction survey results revealed that most respondents were satisfied at the highest level. Augmented reality is used for engagement and incorporates digital images into a physical space with real-world objects interacting with people.

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