Introduction of Product

Development of Wear-resistant Bucket (e-Bucket) for PC200 Series

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KOMATSU Manufacturing Engineering Development Center developed wear-resistant bucket for PC200 series which is marketed as "e-Bucket" from Komatsu All Parts Support Ltd.(KAPS). This paper describes the functions and features of e-Bucket.

Key Words: *Bucket, Wear by Sand and Soil, Wear Resistance, Excavation, Wear Part*

1. Introduction

The bucket of hydraulic excavator is continuously exposed to soil during excavation and most severely worn in all components of the machine. In general, from the cost point of view, buckets are not replaced but regularly repaired for use. Therefore, users always demand durable buckets that can easily be repaired. Besides, as buckets are used to scoop up soil, high excavating capability is also required of them. Our newly developed bucket not only has high wear resistance and excavating capability but also can easily be repaired, so that it can reduce maintenance cost (repair cost) and meet above mentioned user needs.

2. Purpose of Development

2.1 Development of long life bucket

Currently used buckets have problems that they are broken in early stage due to local wear of bottom plate, which is resulted from their shape, and that the life of wear parts mounted on them is insufficient from the beginning. Therefore, we aimed at achieving twice the wear life of current buckets (PC200-7 standard) by changing the shape so that wear would uniformly occur over a whole bucket and reinforcing the wear parts.

2.2 Development of easy-to-excavate bucket

We aimed at improved penetration and the easy-to-scoop bucket by changing the shape of bucket.

2.3 Development of bucket with low repair cost

For cutting repair cost, how to repair buckets is also an importance factor. The easiness of repair means:

① Wear parts can easily be replaced
② Repair parts are made of the materials that can easily be procured. (Namely, low price)
③ Even if wear part is worn out, bucket body should not be damaged as much as possible.

We aimed at meeting all these requirements.

2.4 Development of the bucket that can be purchased with low price

When buckets are purchased, reinforcements are welded on their bottom and side faces for protection against wear (additional reinforcement). This operation is executed as a batch and not efficient because the original wear parts that are already mounted on buckets need to be removed by gas cutting before thicker parts are welded. (If additional wear parts are mounted on already existing ones, the buckets become too heavy.) Therefore, we aimed at increasing the efficiency of this operation to lower the purchasing cost. (**Photo 1**)

Photo 1 Example of repaired buckets

3. Means for Achievement and Test Result

3.1 Development of wear resistant bucket

(1) Achievement of long life by using thicker wear parts and changing the material

If the improvement of wear life is achieved only by increasing thickness, using low grade material, the overall weight will increase to deteriorate the machine stability. On the other hand, if high tensile strength material (high hardness material) is used too much, although lightweight may be achieved, productivity will be lowered due to poor weldability and bending workability, and cost will increase. Therefore, in selecting material, we took the balance of these factors into consideration.

As shown in **Table 1**, side wear part was strengthened by approx. 2.5 (t12) to 3.5 (t16) times by increasing the thickness (1.33 or 1.78 times by thickness ratio) and changing the material (more than twice because tensile strength is almost in inverse proportion to abrasion loss). Bottom wear part was strengthened by 1.33 (t12) or 1.78 (t16) times by increasing the thickness.

Table 1 Comparison of wear part

		e-Bucket	Current bucket (PC200-7)
Side wear part	Material	SHT1080	SHT490
	Thickness	t12 or t16	t9
	Shape	Anchor type	Halberd type
Bottom wear part	Material	SHT1080	SHT1080
	Thickness	t12 or t16	t9
	Shape	Laterally divided 5-piece configuration	Longitudinally divided 3-piece configuration

The increase of thickness also aims at preventing the deformation of bucket. Especially the side face has conventionally had the problem of becoming dented, so that the shape was changed from halberd to anchor type. (**Photo 2**) This makes it possible to prevent damages and easily repair buckets. (Shaping is unnecessary during repair.) All the materials used this time can be procured easily and be bent and welded as easily as conventional materials.

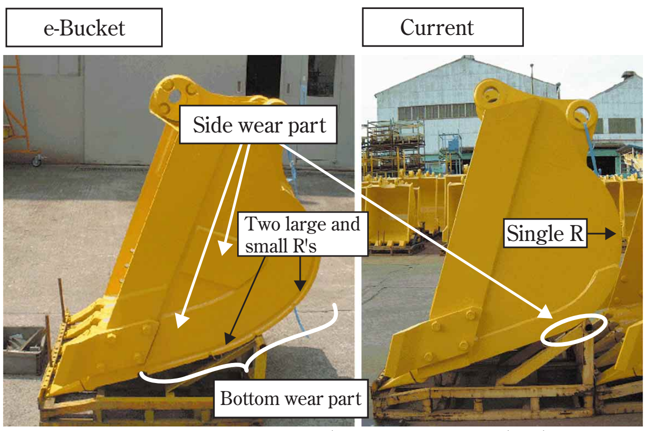


Photo 2 Comparison of the appearance of bucket

(2) Changing the bottom shape to prevent local wear

Current buckets are most severely worn at the portion where the linear line from the tip connects with the curvature of the bottom (circled portion in **Photo 2**). If left as it is, this local wear causes to break the bucket in early stage, which has been an issue for a long time. For e-Bucket, we changed the bottom shape from the current single radius to 2-step radius (**Photo 2**) and succeeded in preventing local wear and achieving a long life. As the pretest of wear resistance, buckets were subjected to 100 times of excavation to the depth of approx. 500 mm from ground surface in order to see how wear range differs between e-Bucket and conventional buckets from the condition of peeled paint. As a result, it was confirmed that e-Bucket has 1.79 times as wide wear range as conventional buckets. (Current bucket: 380 mm; e-Bucket: 680 mm) (**Photo 3**)

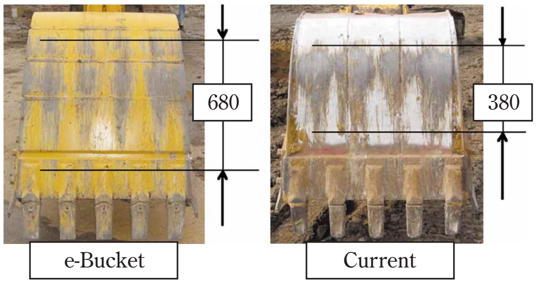


Photo 3 Comparison of wear range

Our concept of this matter is described below:

<Concept for solving the problem of local wear>

We consider why local wear occurs at the portion where the linear line of bucket connects with the curved line. For this, it is necessary to investigate which of boom cylinder, arm cylinder and bucket cylinder becomes the main cause of the local wear when they are used for excavation.

- Excavation with boom cylinder - Bucket only moves up and down when boom is moved up and down. There is no movement to rub the bottom of bucket. Therefore, no wear occurs on the bottom in this case.
- Excavation with bucket cylinder - As shown in **Fig. 1**, a perpendicular line is dropped from the center of bucket toward the bottom, and a circle whose radius is the length of the perpendicular line element is drawn. Then, the portion of bucket that lies outside this circle must be most severely worn. Namely, wear must occur mostly around tooth and front lip. (Bold circle in **Fig. 1**) This, however, cannot explain the reason why wear occurs on the bottom of bucket.

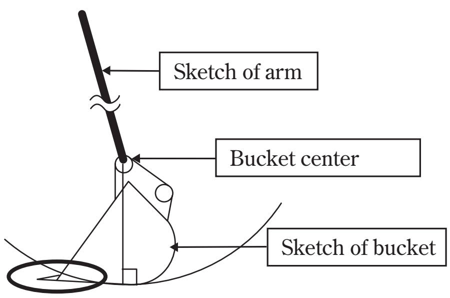


Fig. 1 Wear suffering portion when excavation is made with bucket cylinder

- Excavation with arm cylinder

A circle (circle A) whose radius is the distance between the arm mounting center and the tooth center is drawn and then changed radius such that it comes in contact with the bucket bottom (circle B). Then, the contact point becomes the point that is the furthest from the arm mounting center, or the point that is most strongly rubbed against ground surface and therefore most severely worn when excavation with arm cylinder is executed from the contact point of 30° in arm angle. We simulated how the contact point is displaced during excavation, or when the arm is displaced (at 55° in the **fig. 2**), and found that the displacement of the contact points are concentrated around the portion where the linear line of bucket connects with the curved line having the circular arc (bold circle in the **fig. 2**). We thought this must be the cause of local wear. Therefore, for e-Bucket, the bottom shape was determined such that the displacement of the contact point is doubled as shown in **Photo 4**. (This results in 2-step radius because the shape with superposed two circular arcs is best.) And we succeeded in obtaining a value that is nearly equal to 1.79 times that had been obtained in the pretest described above. According to this fact, we believe that the shape with 2-step radius will effectively prevent wear.

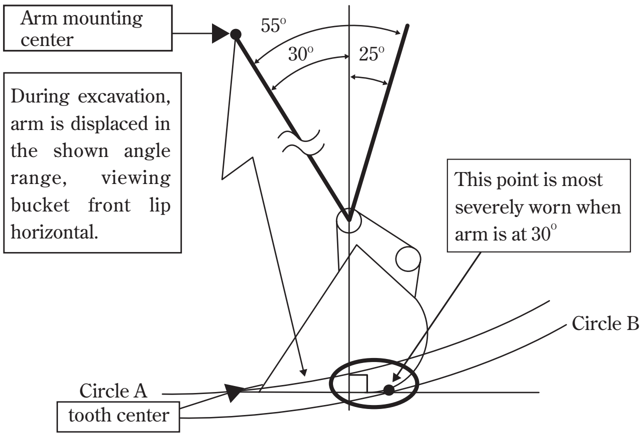


Fig. 2 Wear suffering part when excavation is made with arm cylinder

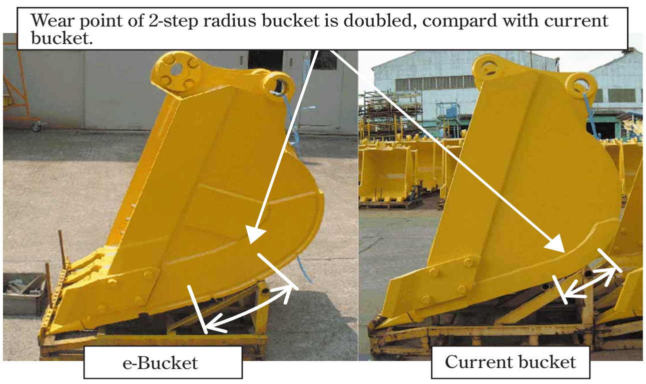


Photo 4 Difference of supposed wear range under the same displacement of arm

(3) Result of wear test with actual machine: Test machine = PC200-7, Operating time = 394 hours

The life of side plate was slightly shorter than our expectation, or 1.93 times. On the other hand, the life of bottom plate was 2.00 times, which is larger than the value obtained by material change (**Table 2**). This is because the effect of local wear prevention, which is achieved by shape change, is included. We checked how wear progresses in reality, the result of which is shown in **Fig. 3**. Abrasion loss at the most severely worn portion is recuded by 39%, compared with current bucket. We think that this is the reason why the wear life of bottom plate was increased. According to these results, and comparing buckets at the timing of purchasing, e-Bucket has twice as long life as current bucket. Comparing buckets that are repaired in the same way after operated for given period, e-Bucket has 1.4 times as long life as current bucket.

Table 2 Result of wear test performed by Test Engineering Center.

Part	Life assumed from residual thickness (hr)		Target	Result
	e-Bucket	Current bucket		
Side wear part	10,400	5,400	Twice	1.93 times
Bottom wear part	2,800	1,400	Twice	2.00 times

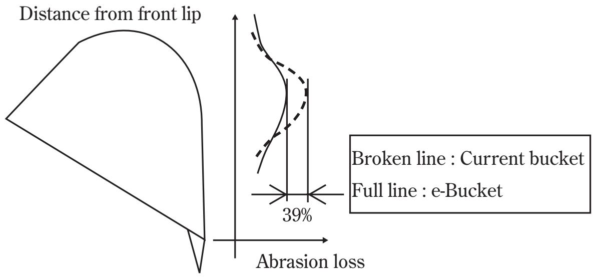


Fig. 3 Comparison of wear condition

3.2 Development of easy-to-excavate bucket

(1) Improvement of penetration and bucket filling

This time, we improved penetration and bucket filling to improve excavating capability. For penetration, as shown in **Fig. 4**, we devised such that tooth is raised more upward by approx. 3° with the same position of bucket hinge pin. Namely, when excavation with arm cylinder is started at the same arm and bucket positions as curernt buckets, bucket is driven in ground more horizontally with respect to ground surface, which reduces excavation resistance and improves penetration. Bucket filling is improved by employing the shape of 2-step radius. We coonsider how soil enters the bucket, according to **Fig. 5**. When soil is sucked in the bucket with single radius, it cannot climb but drops along the buttom because the gradient of bottom is too large. (Compared with the shape having 2-step radius, the length of the bold line in **Fig. 5** is short.) This results in becoming a resistance to make it hard for soil to enter the bucket. When the bottom has the shape of 2-step radius, the soil, which is raked in the bucket, climbs the gently-sloping bottom and gradually gathers there. If soil can smoothly enter the bucket, excavation distance must be shortened and excavation capability must be improved. Thus it does not require unreasonable digging position where tooth angle must be increased to rake soil in, which results in increased excavation resistacne.

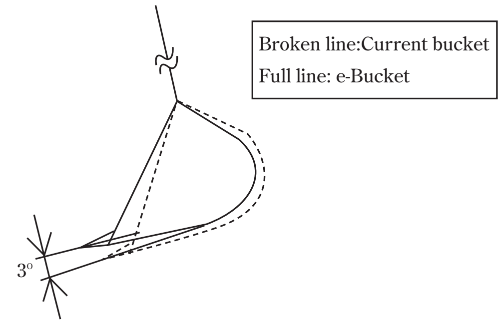


Fig. 4 Difference of tooth approach angle during excavation

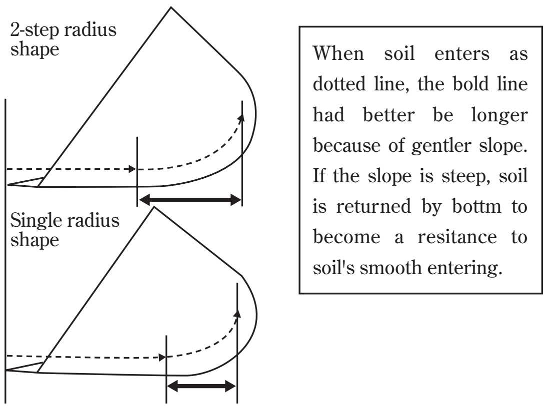


Fig. 5 Comparison of how soil enters bucket

(2) Excavation capability confirmation test performed by Test Engineering Center.

① Loading production confirmation test (tested machine: PC200-7)

As the effect of e-Bucket on excavation work was studied in above (1), the cycle from excavation through swing to loading was repeated given times for individual operation mode to compare the fuel consumption, as the quantity of consumed fuel per unit of loading production, between current bucket and e-Bucket (to confirm that improved excavation capability contributes to lower fuel consumption). No effect of improvement was recognized in the case of the excavation mode where the easiness of bucket's scooping up soil does not come into question, for example soft ground like sand or gravel or underground excavation where soil naturally enters the bucket. On the other hand, when the bucket filling has an influence on excavation, such as hard soil excavation or excavation near ground surface and excavation with lowered digging force, the effect on fuel consumption was recognized. (1 - 5% reduction of fuel consumption in five types of work) Therefore, it can be said that fuel consumption is improved by improving excavation capability as a whole.

② Workability confirmation test

Sensory evaluation test was executed in each actual operation. For excavation (from scooping to earth removal of different hardness of soil), workability is evaluated well. On the other hand, for ground leveling (usual leveling and leveling with swing), workability is lowered because of slightly short linear portion of bucket which is resulted from the employment of 2-step radius shape. However, sensory evaluation evaluated this decrease as small and becoming no problem in actual work

3.3 Development of repair-free bucket

(1) Structure to protect bucket body from damages and easy replacement of wear part

① Improvement of welded construction

Current bucket is structured such that side plate protrudes from bottom plate. (**Fig. 6**) Therefore, as wear progresses on the bottom, weld metal (△ in **Fig. 6** is weldment) is worn and finally weldment is damaged, resulting in plates' being separated from each other. To prevent this, bottom wear part must be replaced although it has sufficient wear allowance and still effectively guarding the main body. (This is a loss of wear part as there is still sufficient wear allowance.)

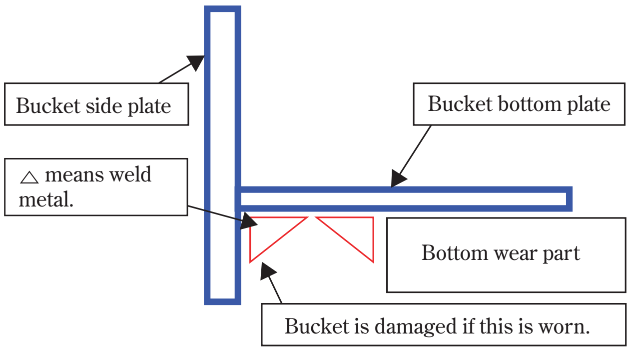


Fig. 6 Welded construction of current bucket

e-Bucket is structured such that not side plate but bottom plate protrudes. (**Fig. 7**) This structure can prevent the weldment between side and bottom plates from wearing. As a result, bucket is less susceptible to damage even when wear parts are worn out. Besides, we can check visually check condition of bottom wear part to determine when to replace it.

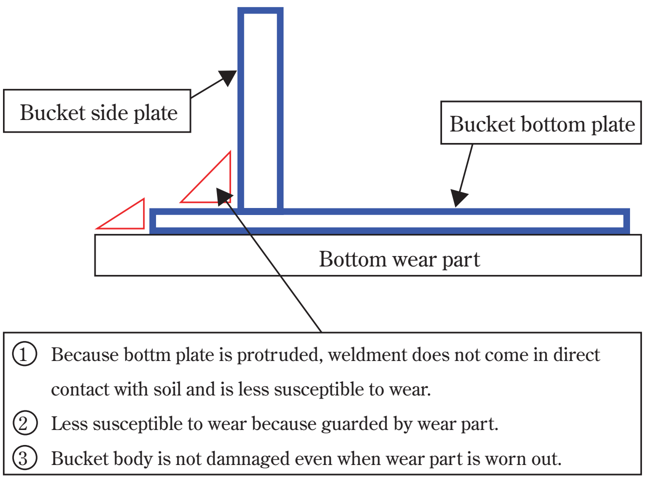


Fig. 7 Welded construction of e-Bucket

② Changing the shape of wear part

The bottom wear part of current bucket is longitudinally divided into 3 pieces. On the other hand, the bottom wear part of e-Bucket is laterally divided into 5 pieces. (**Photo 5**) Because the pieces of wear part are mounted laterally, the wear of weld metal due to soil does not occur, which effectively prevents them from being separated during operation. Besides, it is possible to replace only severely worn pieces, which effectively cuts repair cost.

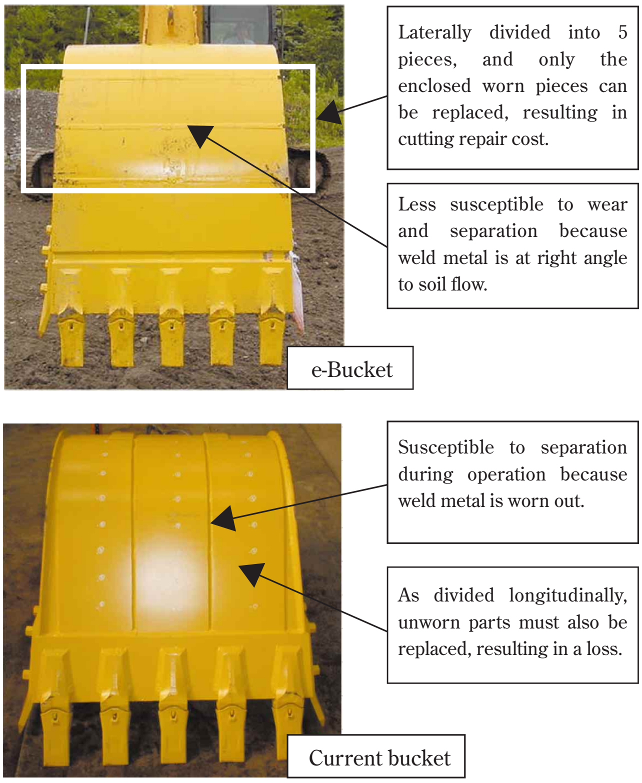


Photo 5 Comparison of the shape of bottom wear part

3.4 Development of low-cost bucket

If additional reinforcement is made outside the production line, lead-time and cost increase to a large extent. Therefore, we, together with KAPS, developed the system to consign additional reinforcement directly to bucket venders from distributors. By this, it became possible to manufacture the buckets with additional reinforcement that meet user needs on the production line and thus to cut production cost and lead time. e-Bucket cost is approx. 12% lower than that of current buckets on which the same level of additional reinforcement is made. (This value of reduction ratio is the average of the places surveyed.)

4. Synthetic Evaluation

According to above explained result of quality confirmation, the advantages of e-Bucket can be summarized as follows: The evaluation of users is also introduced here for your reference.

- Comparing buckets without additional reinforcement, e-Bucket is 1.3 times in purchasing cost and twice in life.
- Comparing buckets with additional reinforcement, e-Bucket is 0.88 times in purchasing cost and 1.4 times in life.
- Improved excavation capability and fuel consumption (max. 5%)
- Wear life after repair is 1.4 times that of current bucket due to prevented local wear. Therefore, repair cost can be cut by 40%.
- Can easily be repaired. ① Only necessary parts can be replaced ② Damage of bucket body can be prevented even when wear parts are worn out ③ Reinforced wear part to prevent the deformation of bucket body)

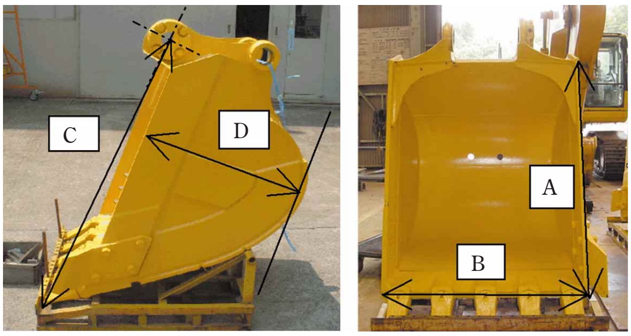
<Users' evaluation>

At the site of hard soil, users highly evaluated the improvement of excavation capability (from scooping to earth removal) and wear resistance. For ground leveling capability, though we had a little anxiety, users evaluated e-Bucket as equal to current buckets. Also for machine balance, because buckets with additional reinforcement were used there, users evaluated e-Bucket as equal to current buckets. At the site of soft soil, evaluation was almost the same as above, except that ground leveling capability is a little lower with e-Bucket than with current buckets. The evaluation at both sites well agreed with that of Test Engineering Center. Namely, synthetic evaluation of e-Bucket is "Good".

5. Comparison of Dimensions between Current Bucket and e-Bucket (Table 3)

Table 3 Comparison of dimentions

		e-Bucket	Current bucket
A	Longitudinal width	1164.5	1199.4
B	Lateral width	1027	1027
C	Sweep radius	1452.9	1477.4
D	Depth	859.7	751
E	Weight (kg)	695.1 Wear part t16 628.1 Wear part t12	564



6. Conclusion

e-Bucket began to be marketed in September 2003 and since has been steadily expanding its sales. Highly reputed by users since the early stage of marketing, e-Bucket is expanding its application, and the models for PC70, PC100 and PC350 series are now under development. We will make efforts also in the future to develop new products that meet user needs. The wear part (shroud) for protection of front lip is provided as option from KAPS because it is not necessary for all sites. By the way, the product was named after the following three concepts, using their initial 'e':

endurance (resistant to wear)
effective (shape to facilitate excavation)
easy maintenance (easily repairable)

Introduction of the writer

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[A few words from writer]

For this development, we started with investigating what sort of bucket users were demanding (what is necessary for a bucket to sell well) and came to be convinced that the improvement of wear resistance of PC200 bucket would be the sales point. And, based on this conviction, we started development. Now, hearing the sales of e-Bucket expanding steadily, we are pleased that our conviction was correct and, at the same time, thank the personnel of related departments and the staff of related manufacturers for their hearty cooperation. In the course of development work, to prevent improved wear resistance from resulting in higher cost, we changed not only the material of wear part but also the shape of bucket, and wrestled also with design problems. In doing so, we had many failures. We must apologize for troubling related departments by these failures, but would like to continue challenging difficulties also in the future, learning from them.